

Science, Service, Stewardship



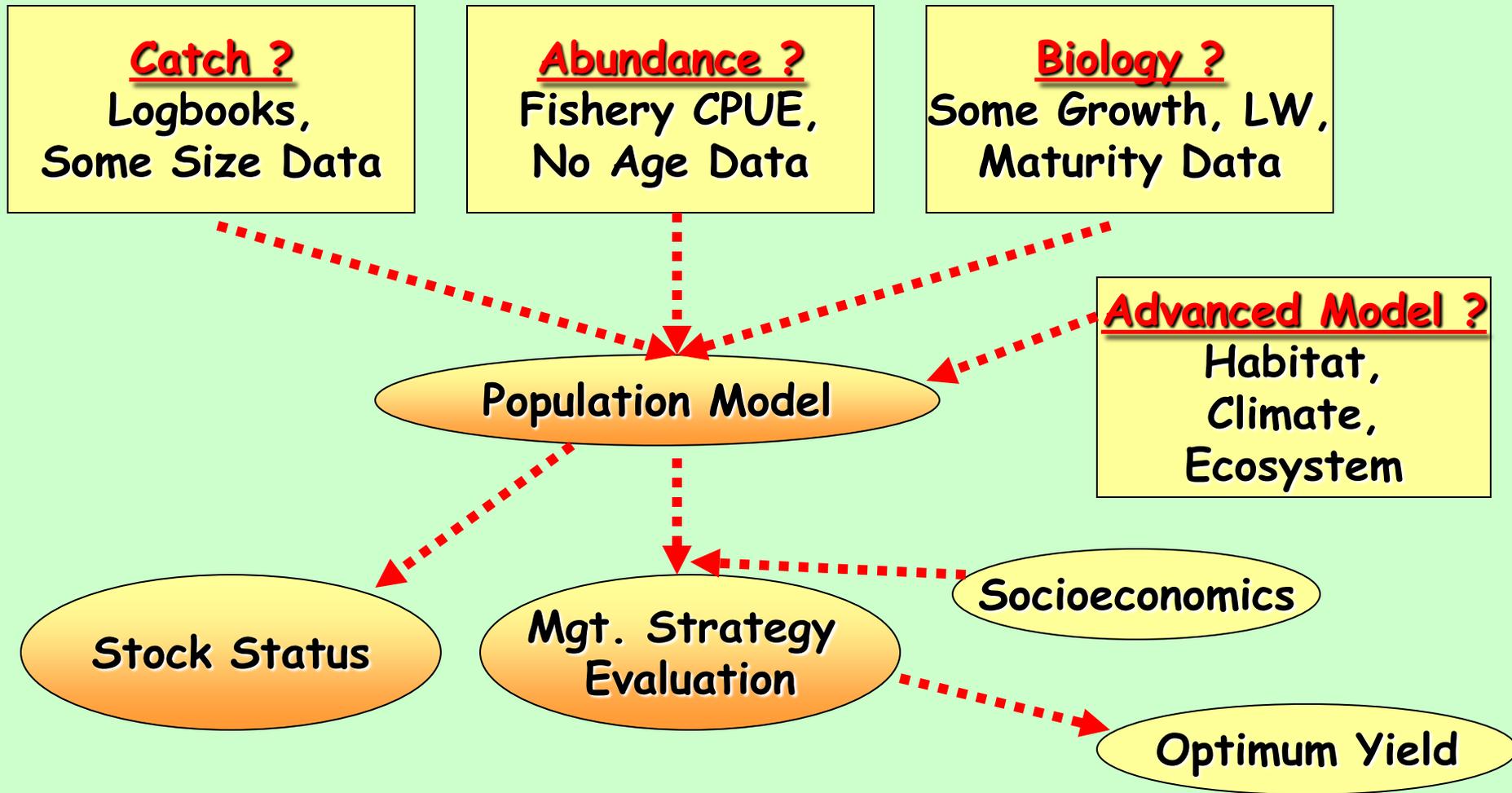
Data-Limited Stock Assessments: Main Hawaiian Islands Bottomfish

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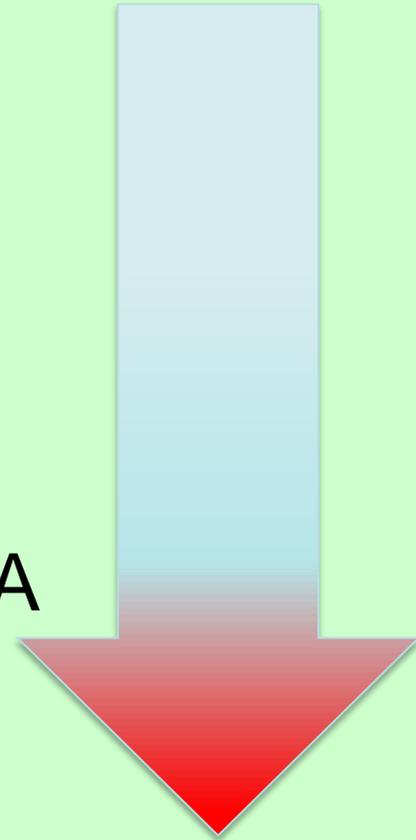
Stock Assessment with Limited Data



ASSESSMENT METHODS

Data Needs

- Fishery Indicators
- Ecological Risk Assessment, e.g., PSA
- Per-Recruit Analyses
- Biomass Production Model
- Age-structured Production Model
- Sequential Population Analysis, e.g., VPA
- Integrated Statistical Models
- Spatially-explicit



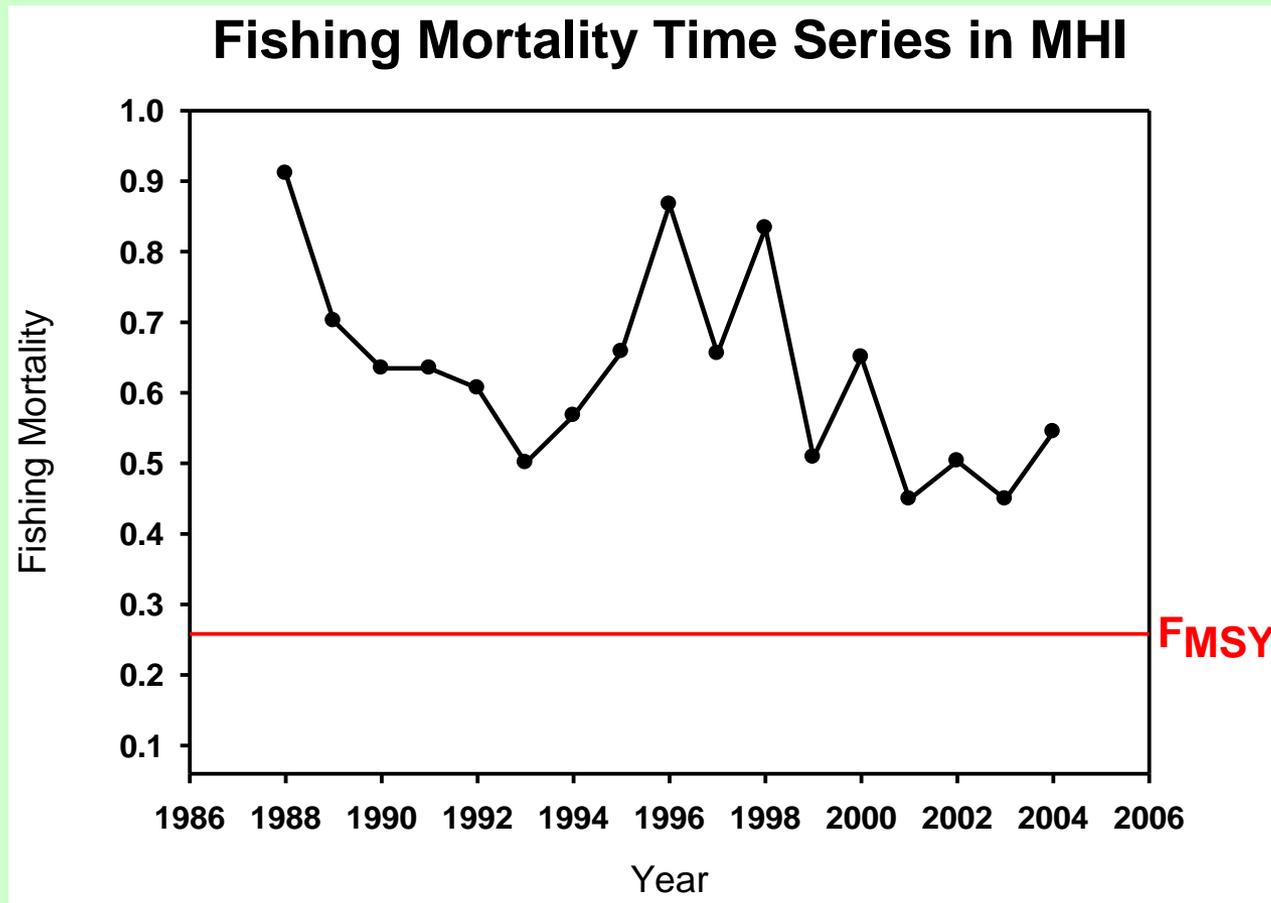
Some are all-in-one tools

Deep7 Bottomfish Life History Information

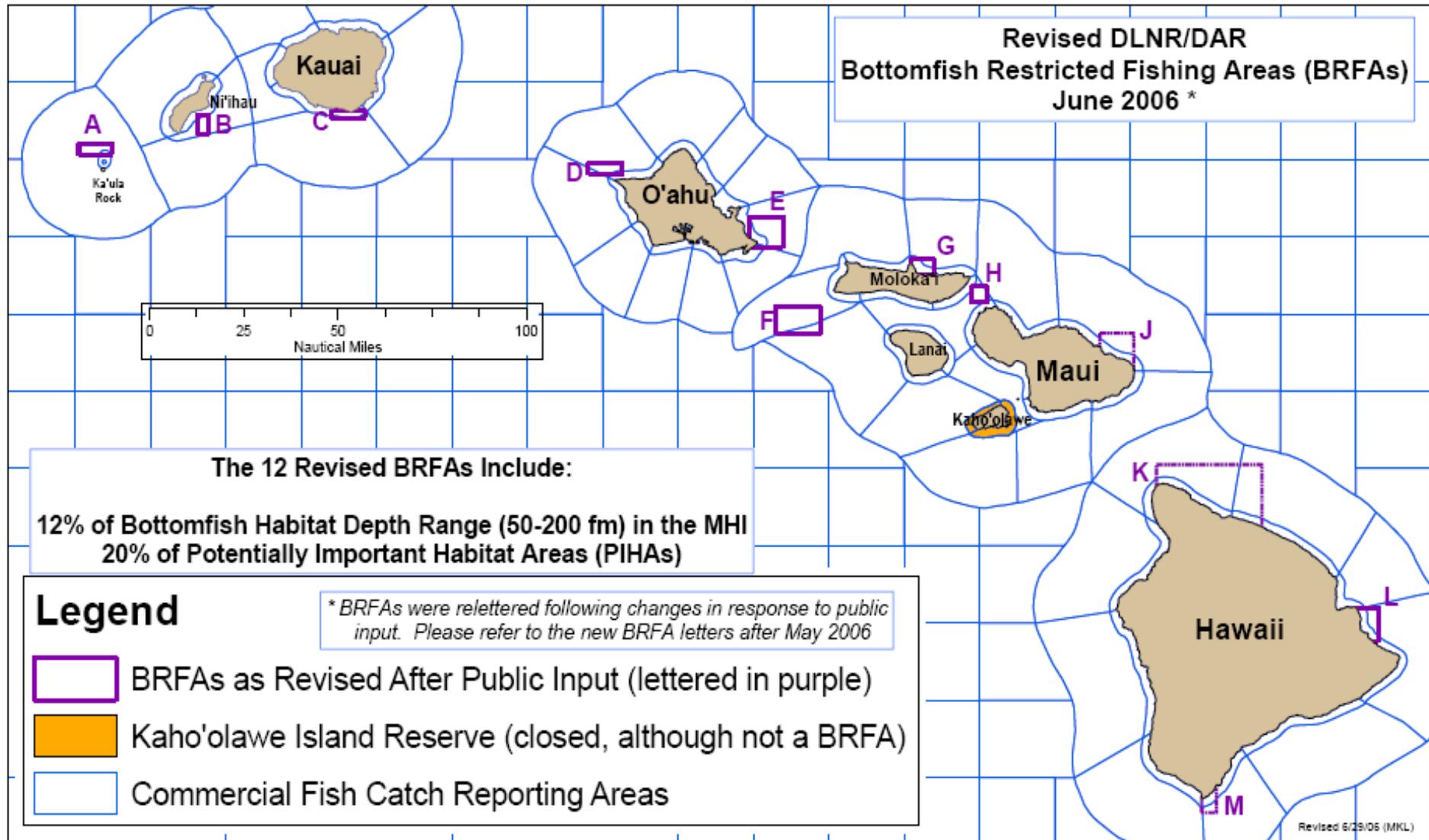
MHI Deep7	Growth	Length-Weight	Maturity	Natural Mortality
Opaka	Yes (various)	Yes	$A_{50} \approx 3-4$ y	$M \approx 0.25$
Onaga	? (n=34)	Yes	?	?
Ehu	? (n=37)	Yes	?	?
Hapu	WIP (n=113)	Yes	$A_{50} > 7$ y	?
Gindai	?	?	?	?
Kalekale	? (n=59)	?	?	?
Lehi	?	?	?	?

Background from 2005 Stock Assessment: MHI Bottomfish Experiencing Overfishing

$$F_{2004} = 0.54 \approx 2 \cdot F_{MSY}$$

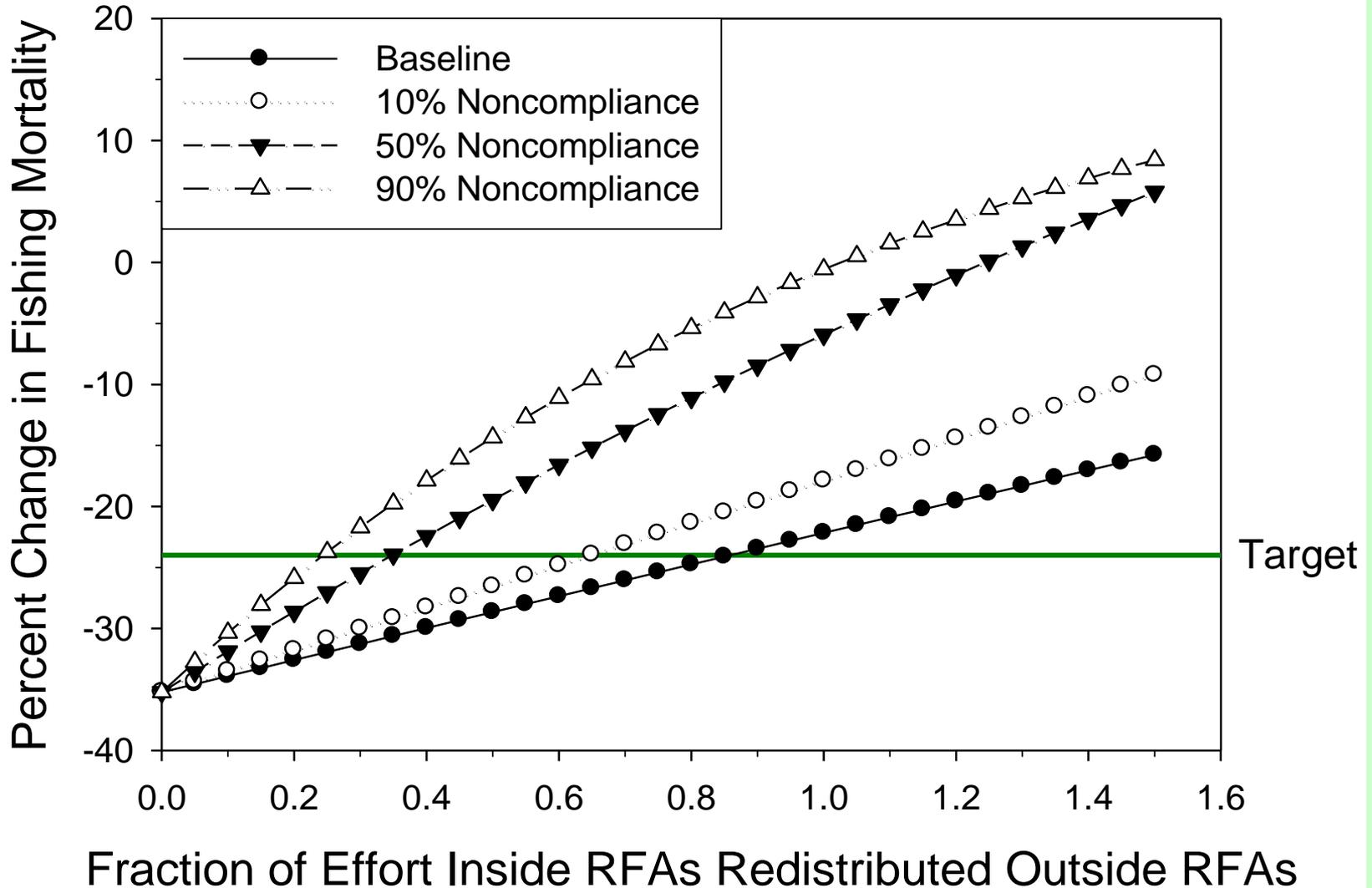


Conservation Measures in Hawaii State Waters: Bottomfish Restricted Fishing Areas



Effects of Noncompliance with BRFAs

Hawaiian Bottomfish Fishing Mortality Reduction
Assuming Constant Baseline Effort Outside RFAs and
Redistribution of Displaced Effort Inside RFAs



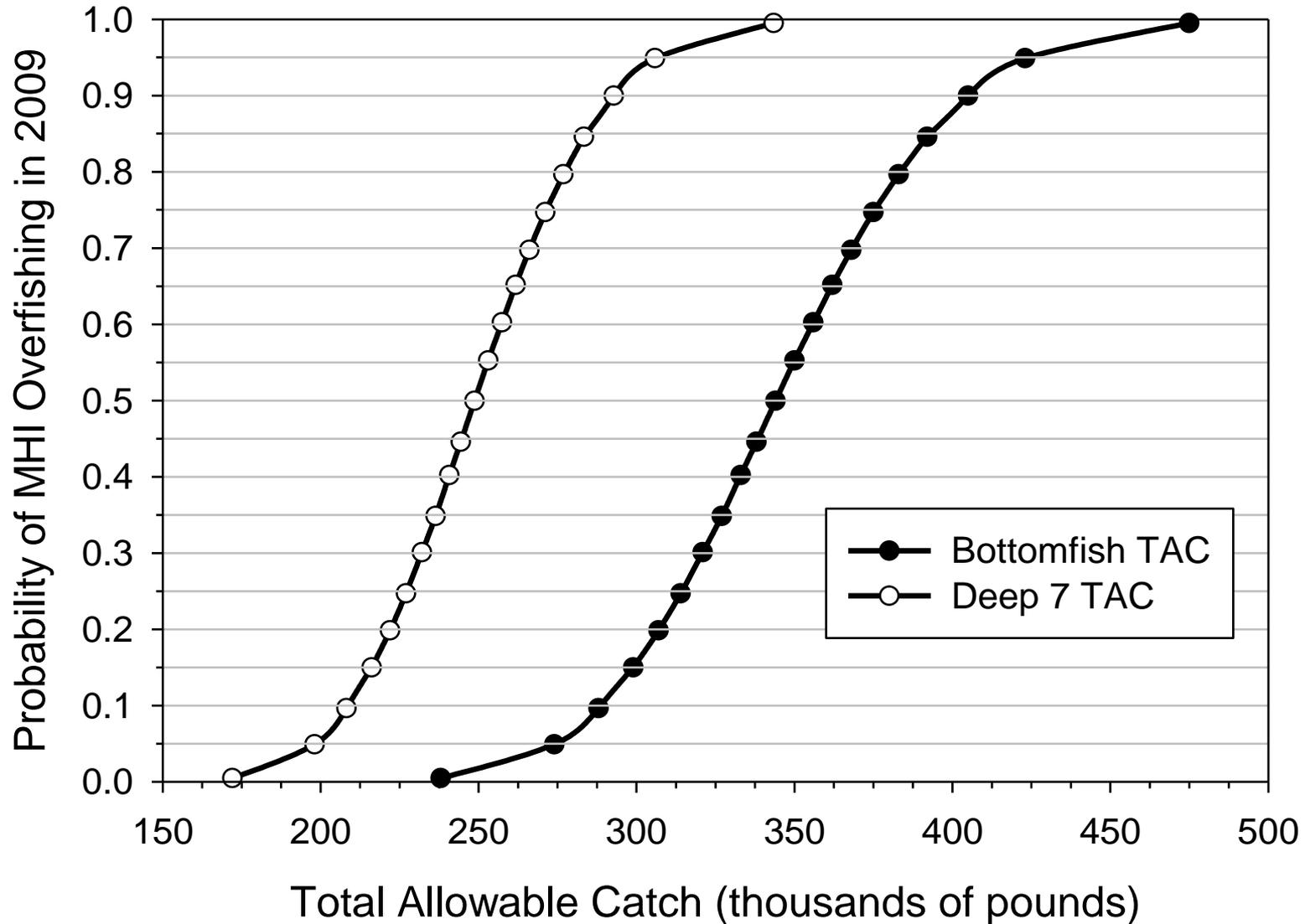
MHI Bottomfish Assessment Data Needs ~ Now

- **Stock structure – more research recommended**
- **Fishery catch – more sampling recommended**
- **Life history & biology – need more information**
- **Relative abundance – fishery-independent survey recommended**
- **Stock assessment – more fishery, biological, and relative abundance data are needed for more accurate approximation of fishery system dynamics**

"Data, data, data ... I can not make bricks without clay."

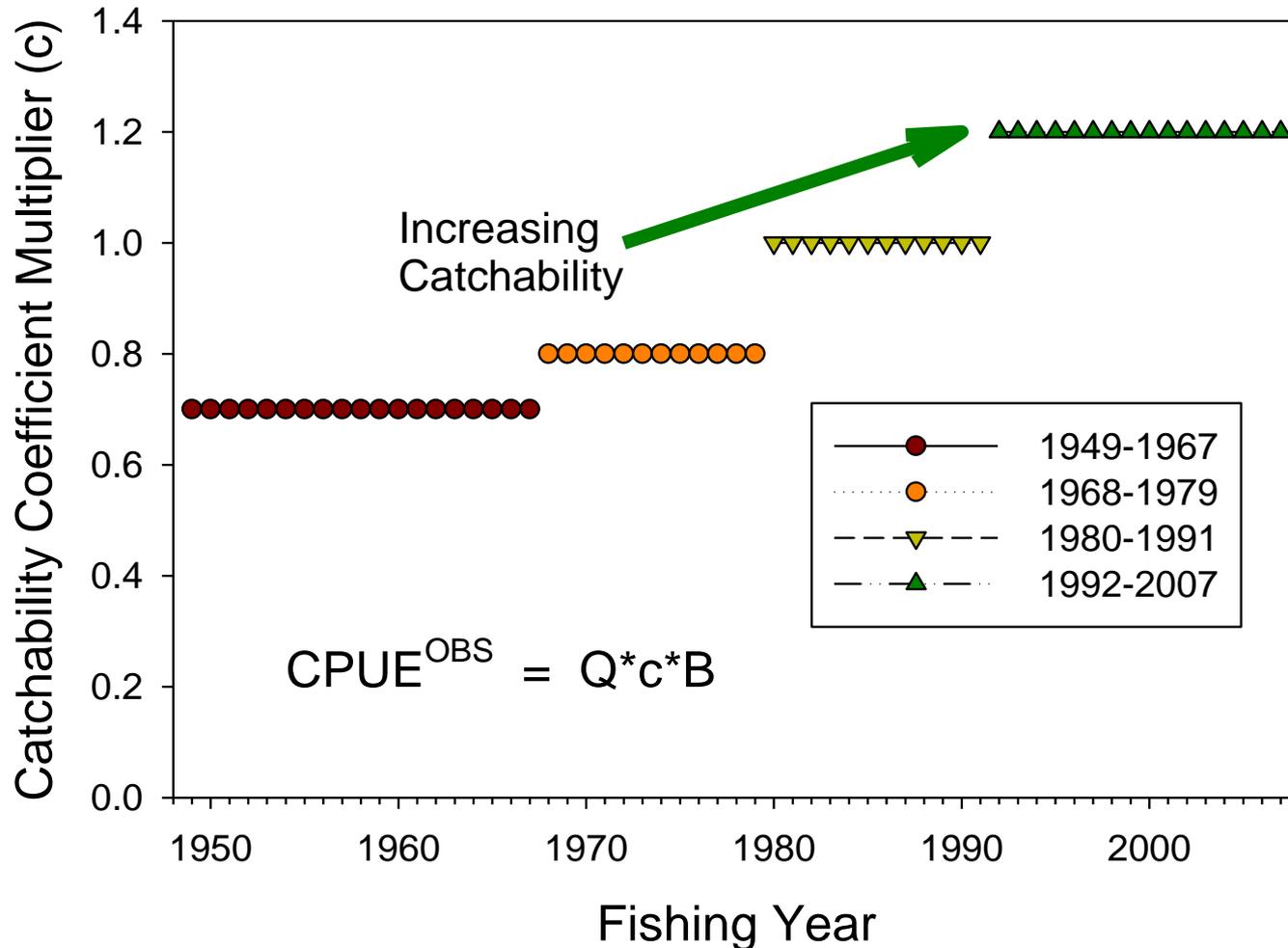
~ Sherlock Holmes, The Adventure of the Copper Beeches

Probability of Overfishing for MHI Bottomfish as a Function of Total Allowable Catch in 2009



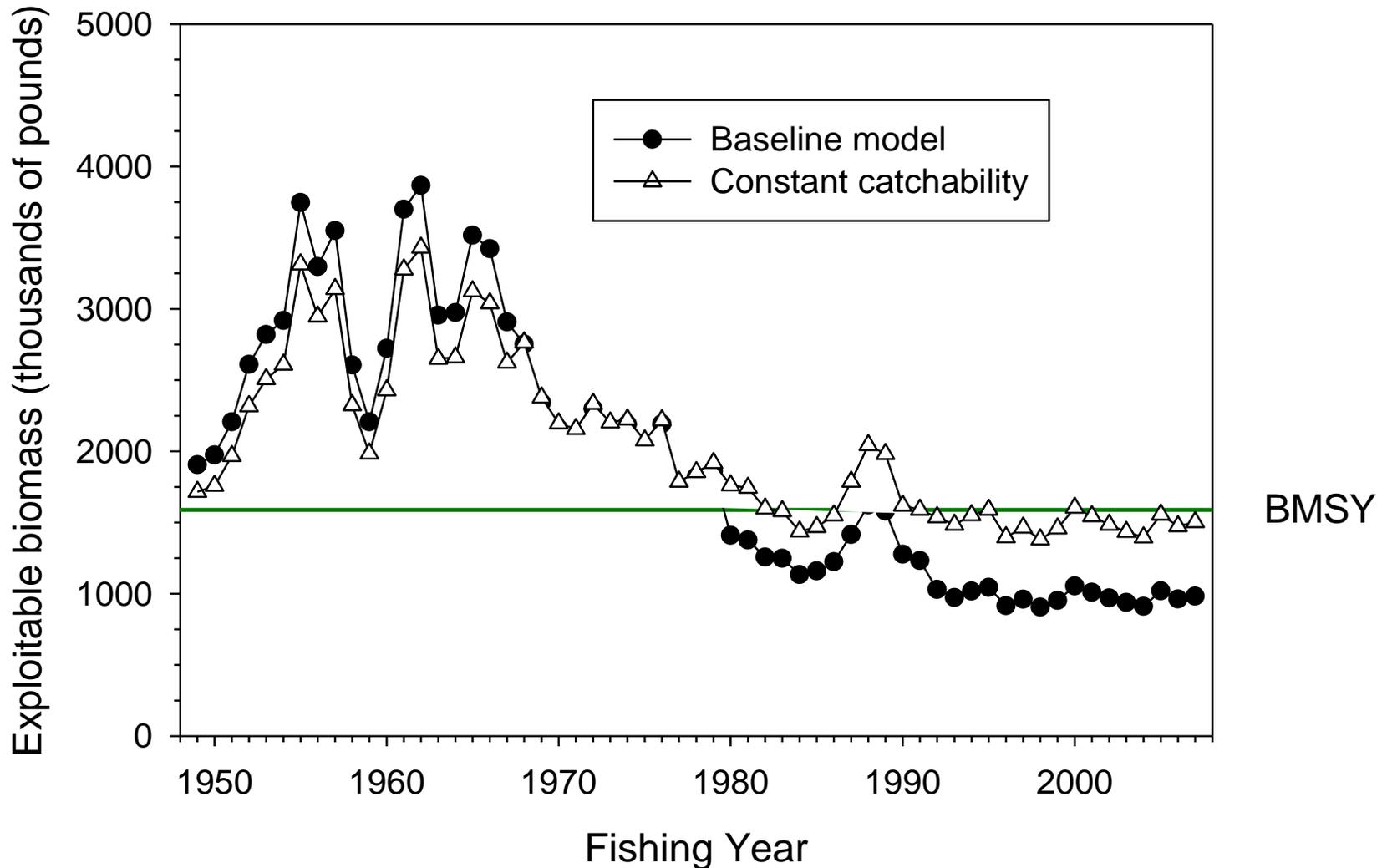
Time-Varying Bottomfish Catchability Used in 2005 Stock Assessment

Adjusting for Improvements in Bottomfish Fishing Technology
Catchability Coefficient Multipliers Used in the 2008 Assessment Update



What if constant catchability was assumed ?

Comparison of estimated bottomfish biomasses in the Main Hawaiian Islands from the Baseline Assessment Model with Time-Varying Catchability and from the Constant Catchability Sensitivity Analysis, 1949-2007

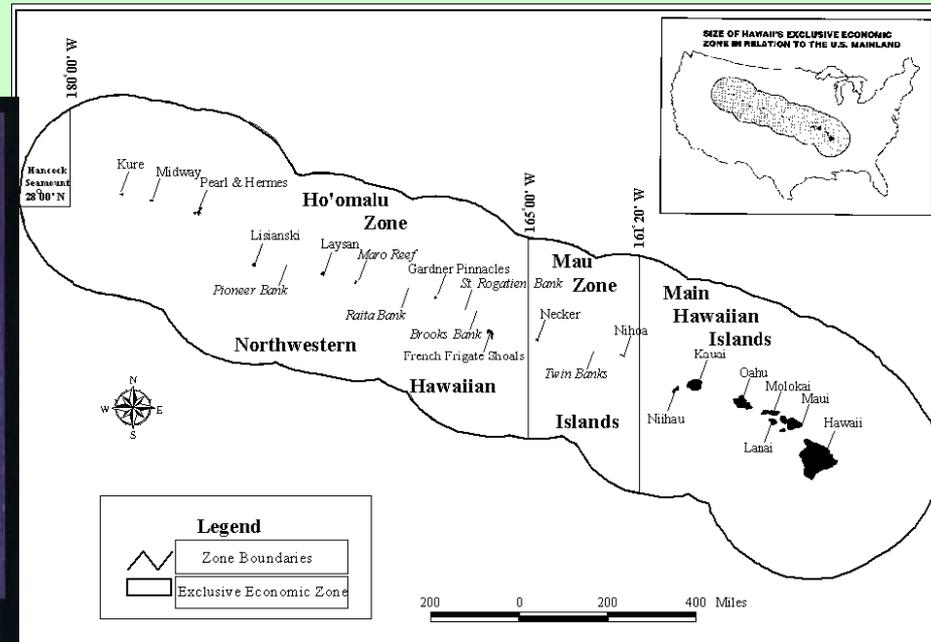


WPSAR 2009 Recommendations for 2011 Assessment

- (i) Construct unreported bottomfish catch histories
- (ii) Develop standardized CPUE series and test impacts of CPUE uncertainty
- (iii) Develop an informative prior for intrinsic growth
- (iv) Assess the Main Hawaiian Islands bottomfish complex as a single unit



ISLANDS AND BANKS OF THE HAWAIIAN ARCHIPELAGO
FISHERY MANAGEMENT ZONES



2011 MHI Bottomfish Assessment

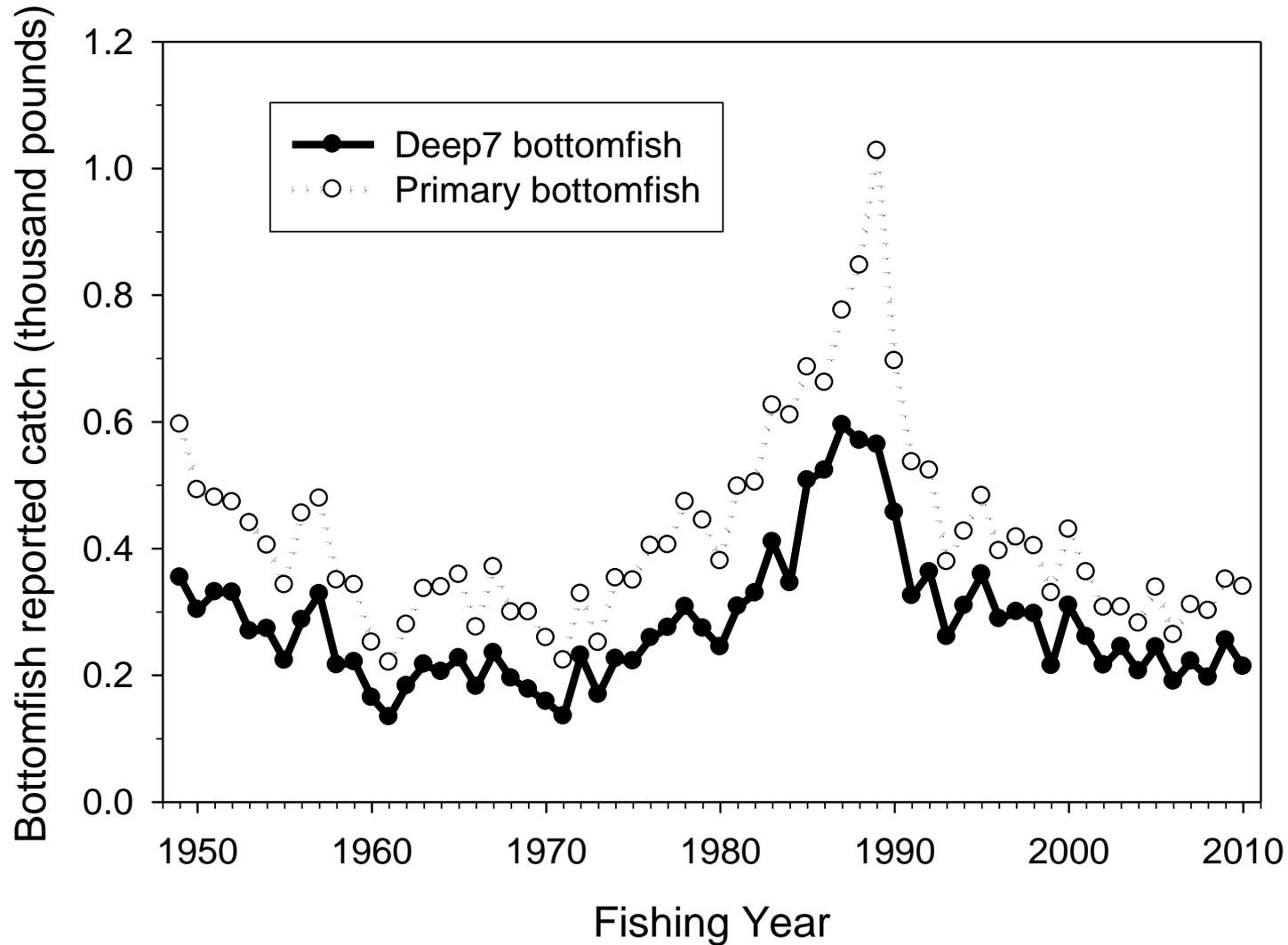
- **Characterize states of nature**
~ what is likely stock status ?
- **Calculate ACL as a function of P^***
- **Identify information needs for improved management**



Overview of Deep7 Hawaii Bottomfish Stock Assessment in 2011 and 2014 Update

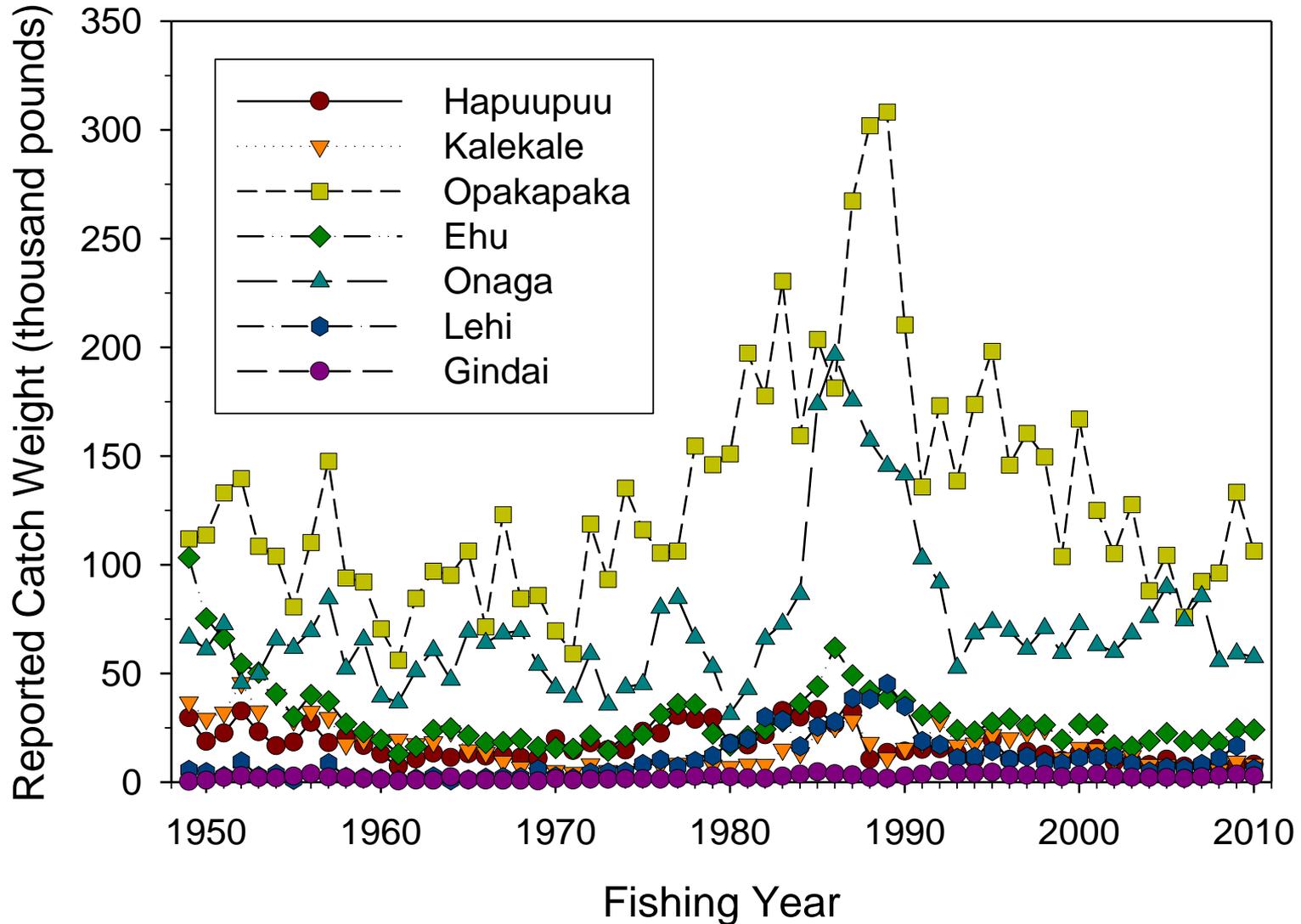
- Main Hawaiian Islands Fishery Data
 - Unreported Catch Data Scenarios
 - Catch-Per-Unit-Effort Catchability Scenarios
 - Multimodel Inference for CPUE Standardization
- Bottomfish Production Model
 - Alternative Input Data Set Scenarios
 - Model Structure
 - Results and Sensitivity Analyses
- Total Allowable Deep7 Bottomfish Catch Projections
 - Commercial Total Allowable Catch (TAC) and Probabilities of Overfishing (P^*) in 2012-2013
 - Decision Tables for Alternative States of Nature

Reported Hawaii Bottomfish Catch Used in the 2011 Assessment



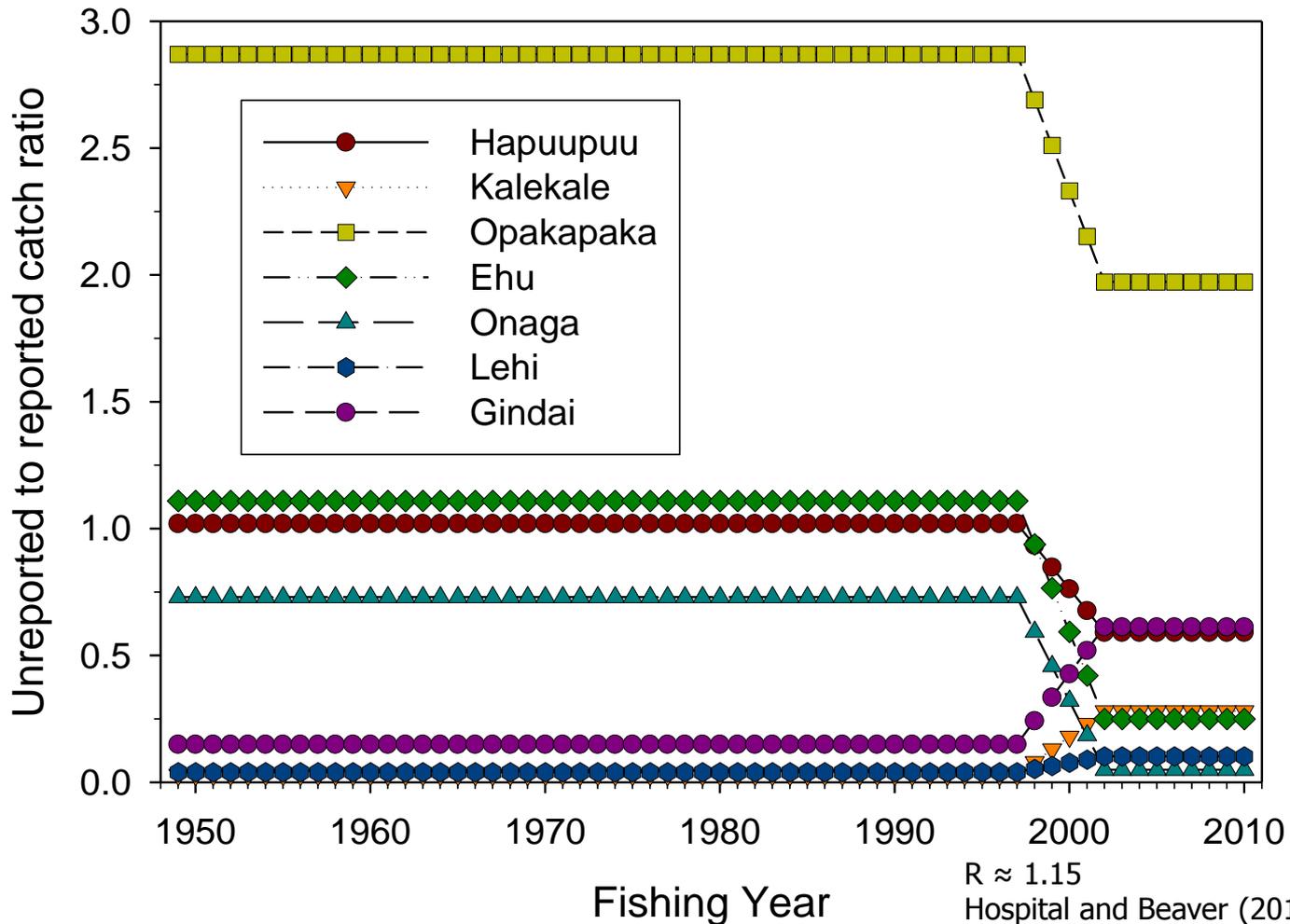
Reported Catch of Deep7 MHI Bottomfish by Species

Reported Catch of Deep7 Hawaii Bottomfish by Fishing Year
For All Catch Scenarios, 1949-2010



Unreported to Reported Catch Ratios of Deep7 MHI Bottomfish Under Baseline Catch Scenario II

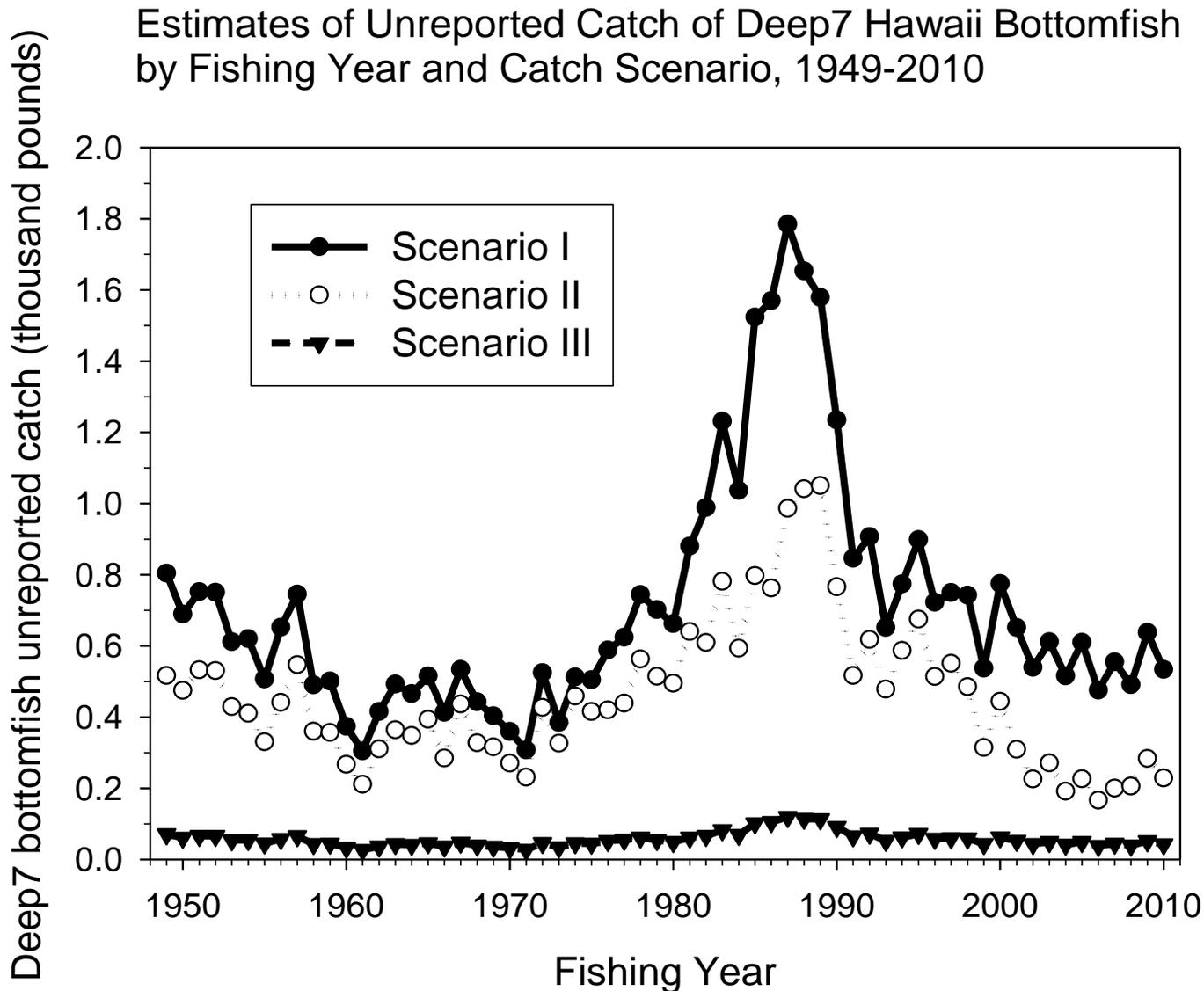
Estimates of Unreported to Reported Catch Ratios of Deep7 Hawaii Bottomfish by Fishing Year Under Baseline Catch Scenario II, 1949-2010



Construct Unreported Catch Histories:

Baseline Catch Scenario (Scenario II)

With Alternative Unreported Catch Scenarios I and III



MHI Bottomfish CPUE Logbook Data

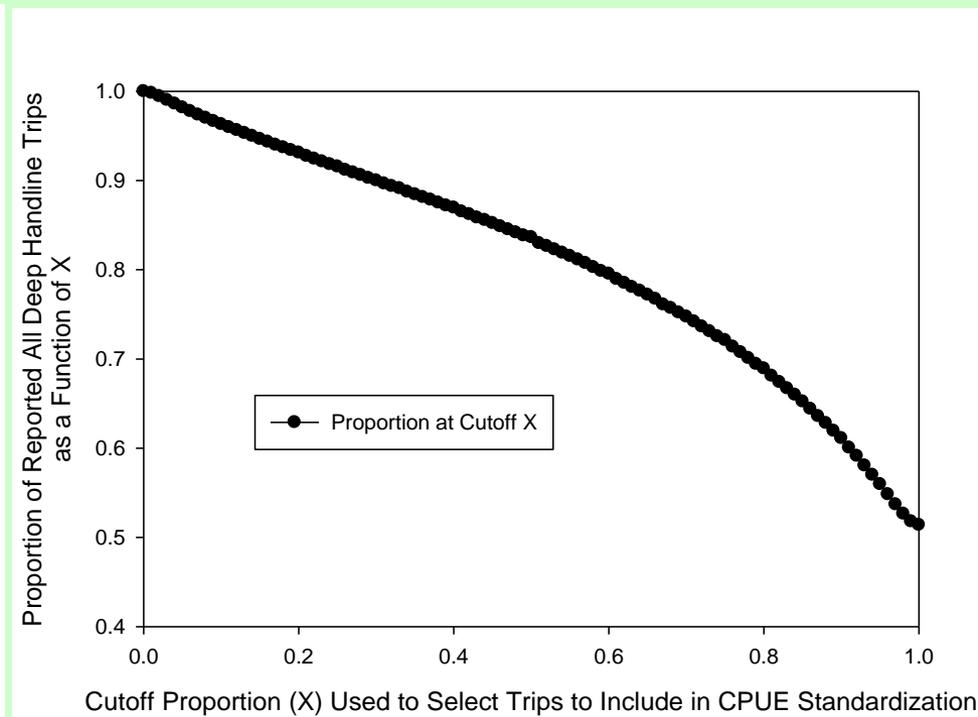
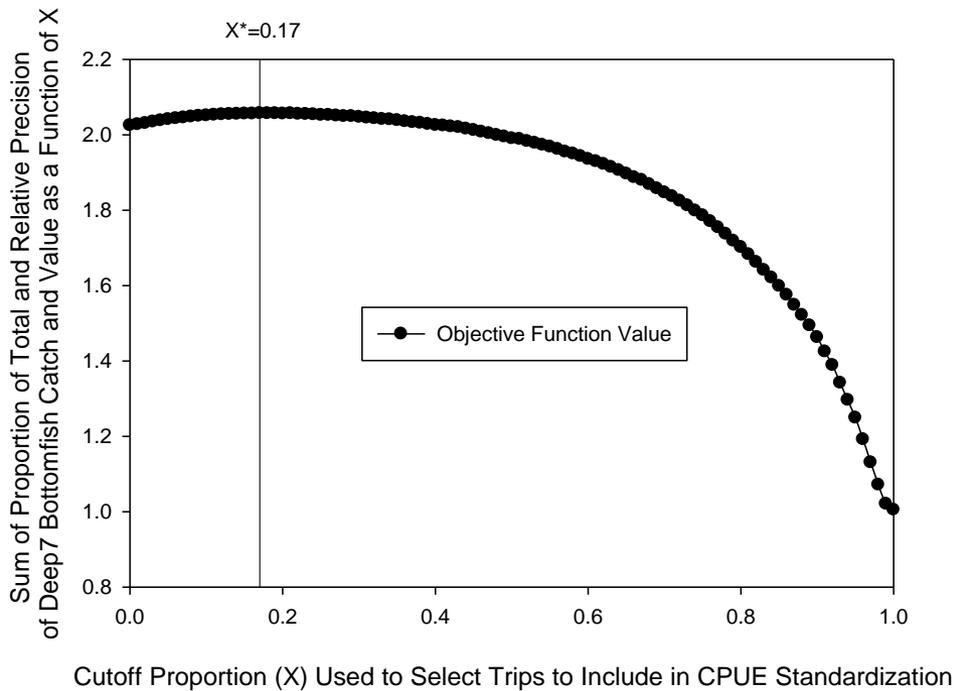
- Hawaii State (HDAR) logbook data, 1949-2010
 - All Deep7 bottomfish catch reports in Main Hawaiian Islands
- Fishing year based on commercial license
 - Fishing Year 1949 is 7/1/48 to 6/30/49
 - Corresponds to Hawaii commercial license period
 - Matches seasonal pattern of spawning and fishery
- Bottomfish single-day trips used in analysis
 - Deep handline gear (accounts > 90% Deep7 catch)
 - 17% Deep7 bottomfish by weight
 - Up to 1500 pounds of bottomfish per day

Develop Standardized CPUE Series:

MHI Bottomfish CPUE Standardization

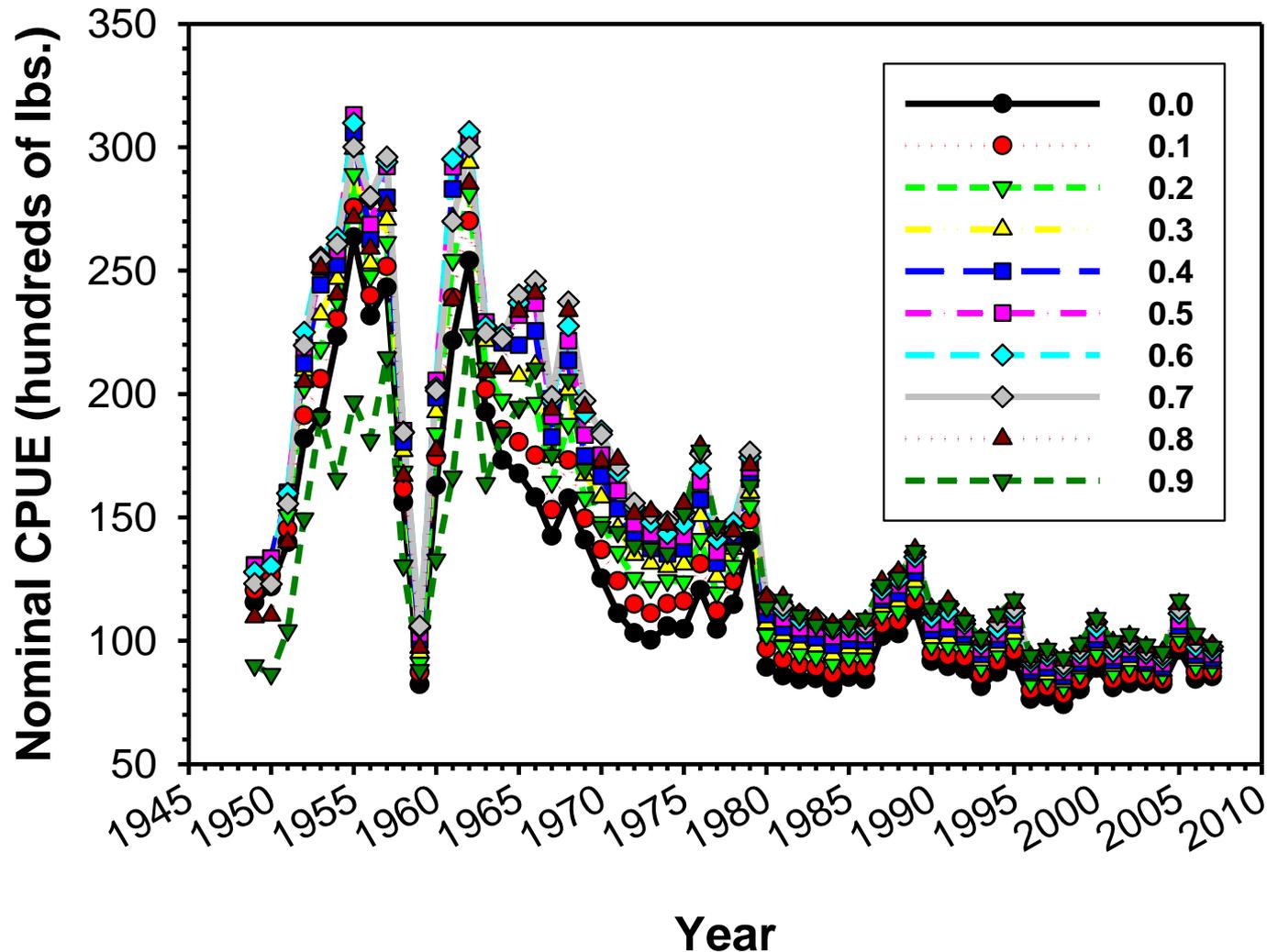
- What logbook information available to standardize CPUE during 1949-2007 ?
 - Fishing year for relative abundance trends
 - Month for seasonal effects
 - Reported fishing area for spatial effects
- HDAR reporting areas for standardization
 - If area accounts for $\geq 1\%$ of bottomfish catch by weight, then treat area as single unit
 - If area accounts for $< 1\%$ of bottomfish catch, then aggregate with local island region (Hawaii, Maui-Nui, Oahu, Kauai)

Choosing a Cutoff Percentage of Bottomfish Catch To Standardize Deep7 MHI Bottomfish CPUE



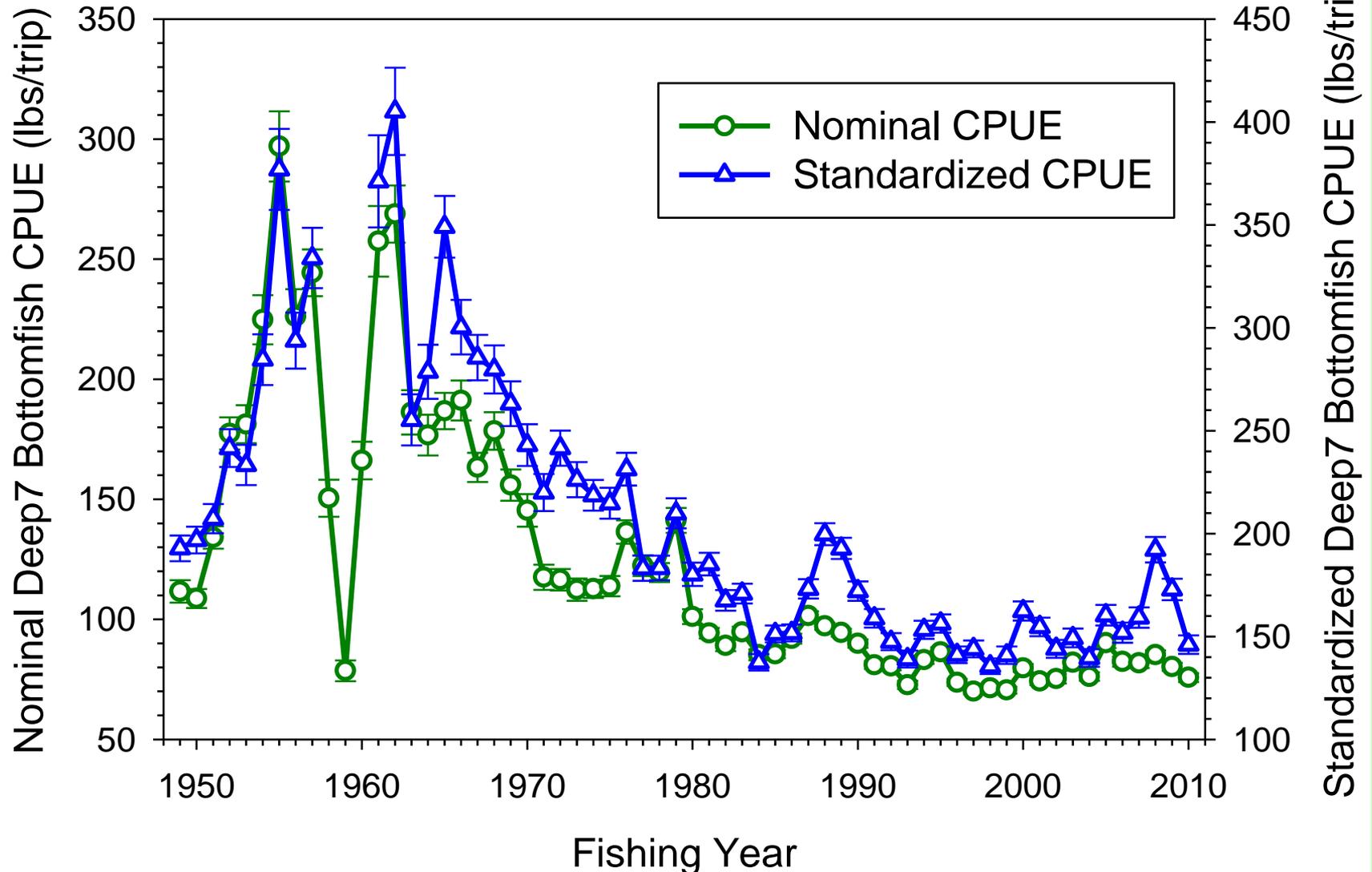
Effect of Percent Bottomfish Trip Catch Cutoff on Nominal MHI Bottomfish CPUE

Nominal Bottomfish CPUE vs. Fishing Year

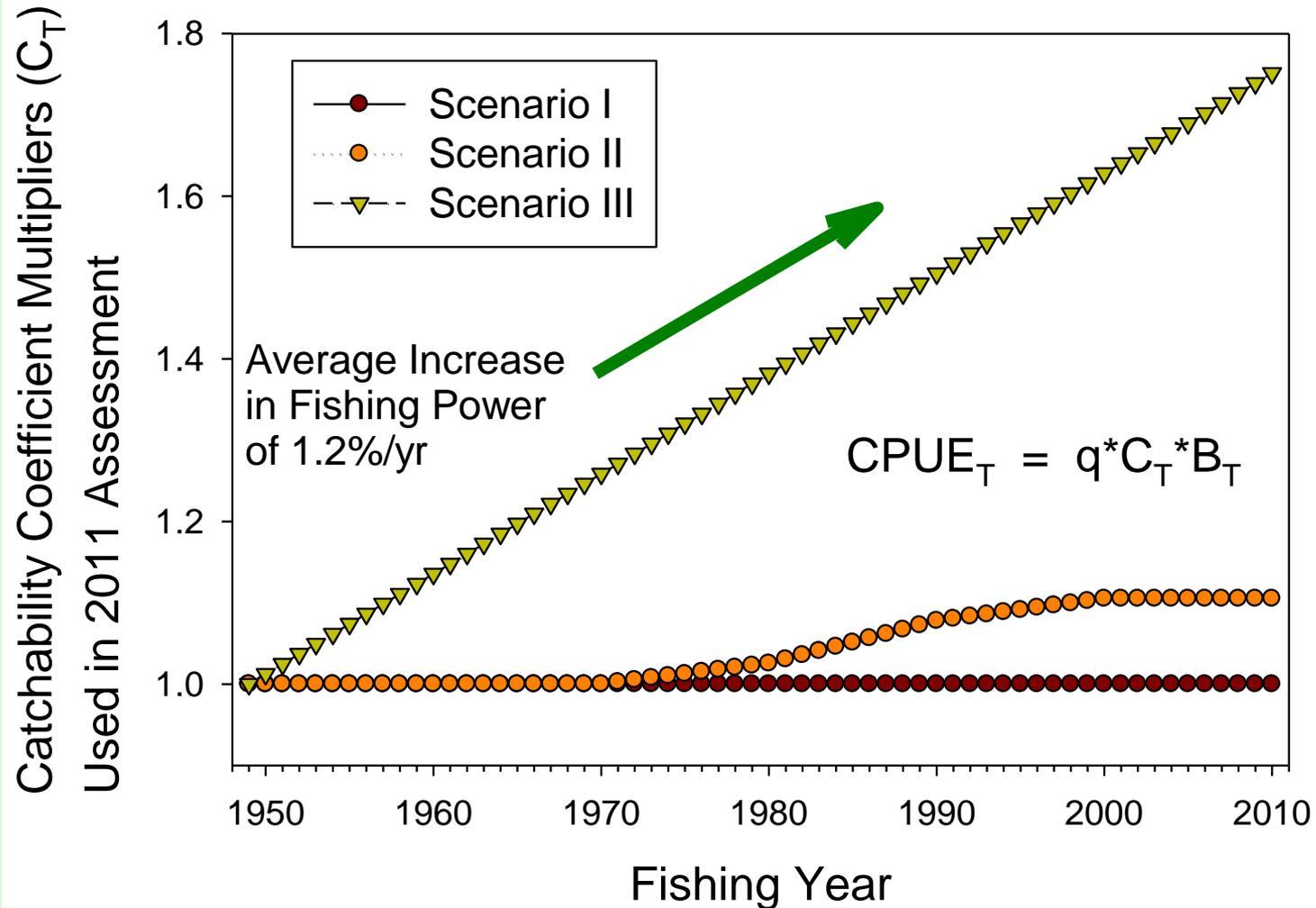


Exclusion of 1958-1960 CPUE Data

Comparison of Nominal and Standardized CPUE of Deep7 Bottomfish Caught with Handline Gear in the Main Hawaiian Islands by Fishing Year, 1949-2010

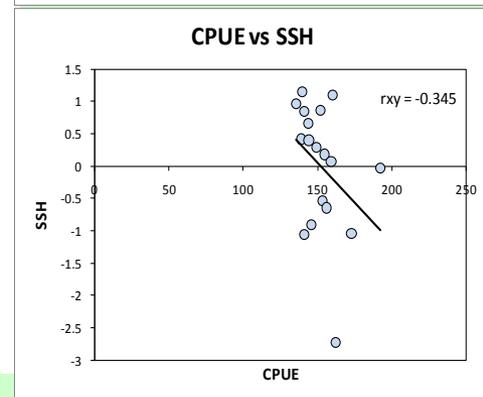
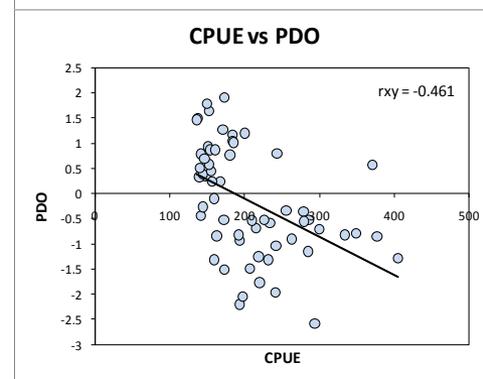
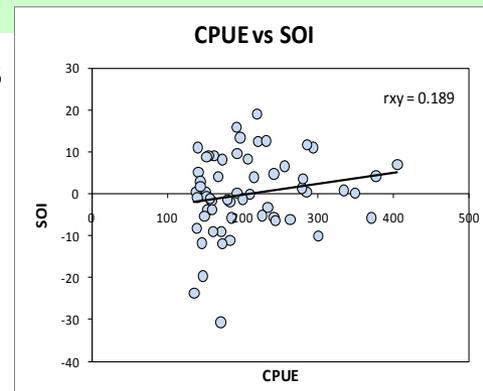
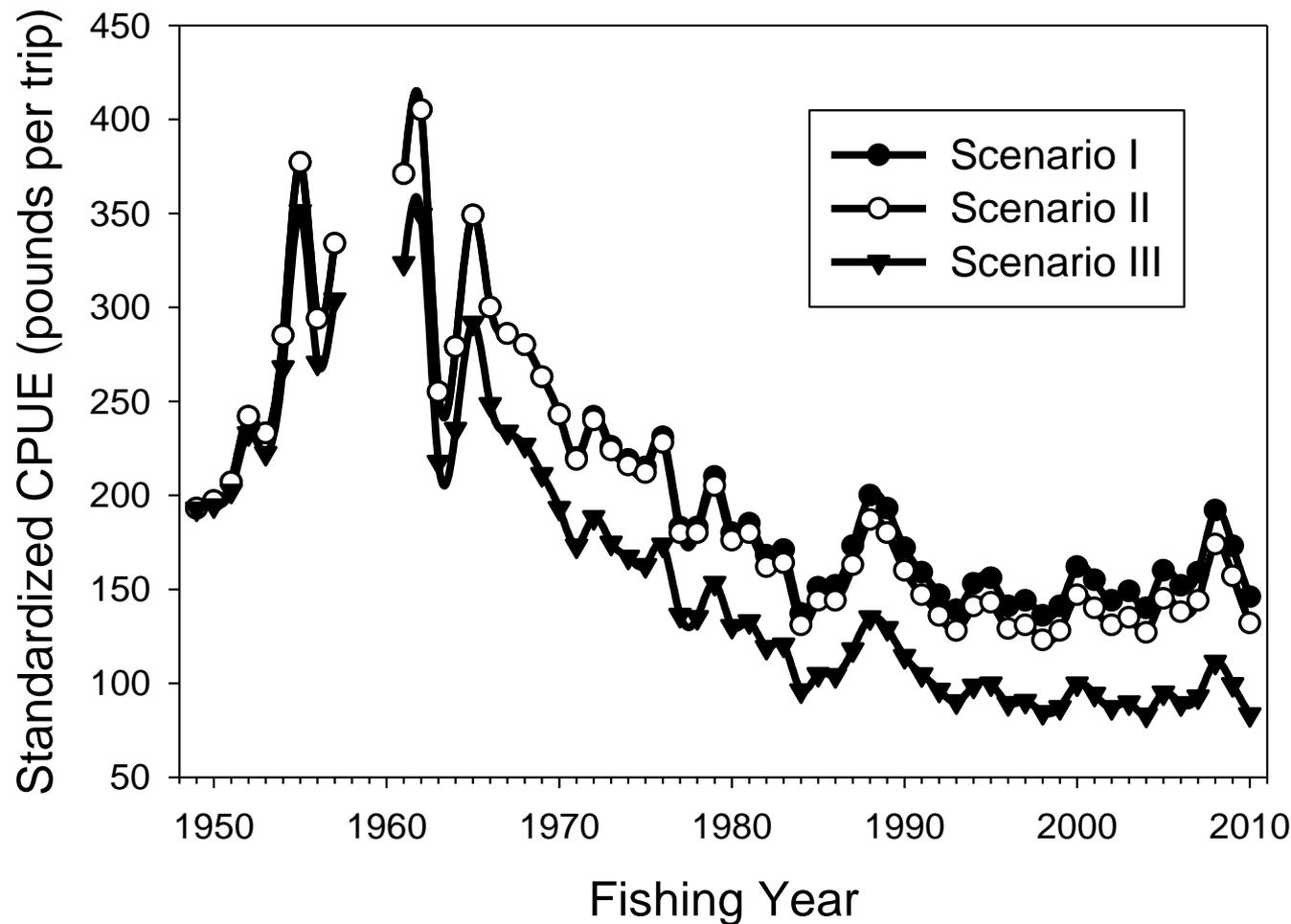


Bottomfish Fishing Power Coefficient Scenarios in 2011 Assessment



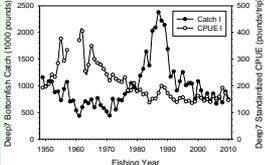
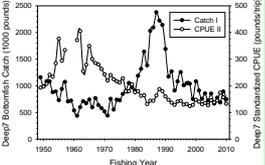
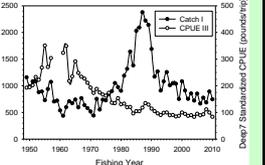
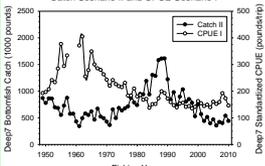
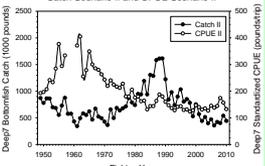
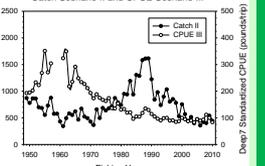
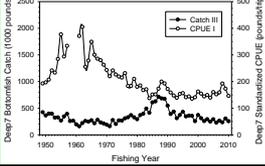
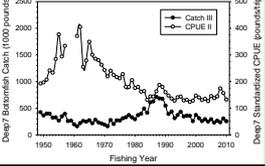
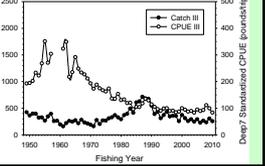
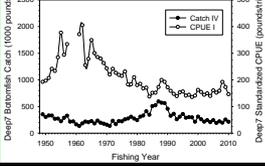
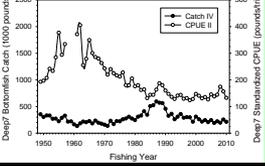
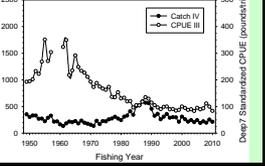
Base Case Bottomfish CPUE Scenario I and Alternative Scenarios and Environmental Correlations

Standardized CPUE of Deep7 Bottomfish in the Main Hawaiian Islands by fishing year and CPUE Scenario, 1949-2010



Catch Scenarios

Catch and CPUE Scenarios

<p>Catch Scenario I</p>	<p>Catch Scenario I and CPUE Scenario I</p> 	<p>Catch Scenario I and CPUE Scenario II</p> 	<p>Catch Scenario I and CPUE Scenario III</p> 
<p>Catch Scenario II</p>	<p>Catch Scenario II and CPUE Scenario I</p> 	<p>Catch Scenario II and CPUE Scenario II</p> 	<p>Catch Scenario II and CPUE Scenario III</p> 
<p>Catch Scenario III</p>	<p>Catch Scenario III and CPUE Scenario I</p> 	<p>Catch Scenario III and CPUE Scenario II</p> 	<p>Catch Scenario III and CPUE Scenario III</p> 
<p>Catch Scenario IV</p>	<p>Catch Scenario IV and CPUE Scenario I</p> 	<p>Catch Scenario IV and CPUE Scenario II</p> 	<p>Catch Scenario IV and CPUE Scenario III</p> 
<p>CPUE Scenarios</p>	<p>CPUE Scenario I</p>	<p>CPUE Scenario II</p>	<p>CPUE Scenario III</p>

Bayesian production model

$$B_{T+1} = B_T + R \cdot B_T \left(1 - \left(\frac{B_T}{K} \right)^M \right) - C_T$$

Process Error

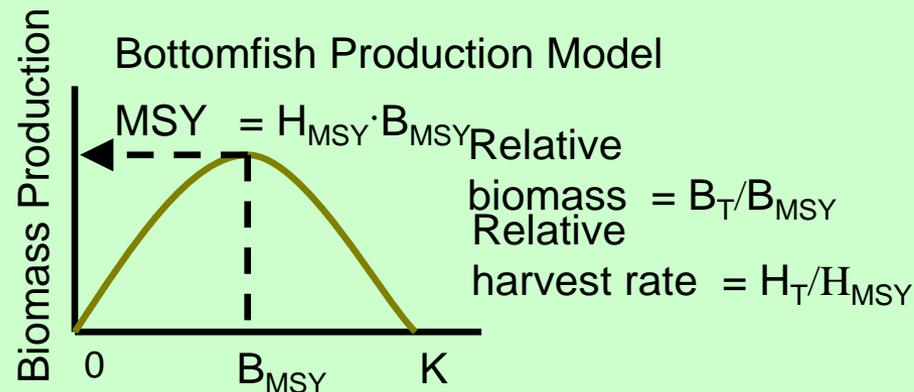
$$P_t = \left(P_{t-1} + r_{t-1} \cdot P_{t-1} \left(1 - P_{t-1}^M \right) - \frac{C_{t-1}}{K} \right) \exp(u_t)$$

$$u_1 \sim N(\mu_{P_1}, \sigma_{P_1}^2) \quad u_t \sim N(0, \sigma^2) \quad t=2, \dots, N$$

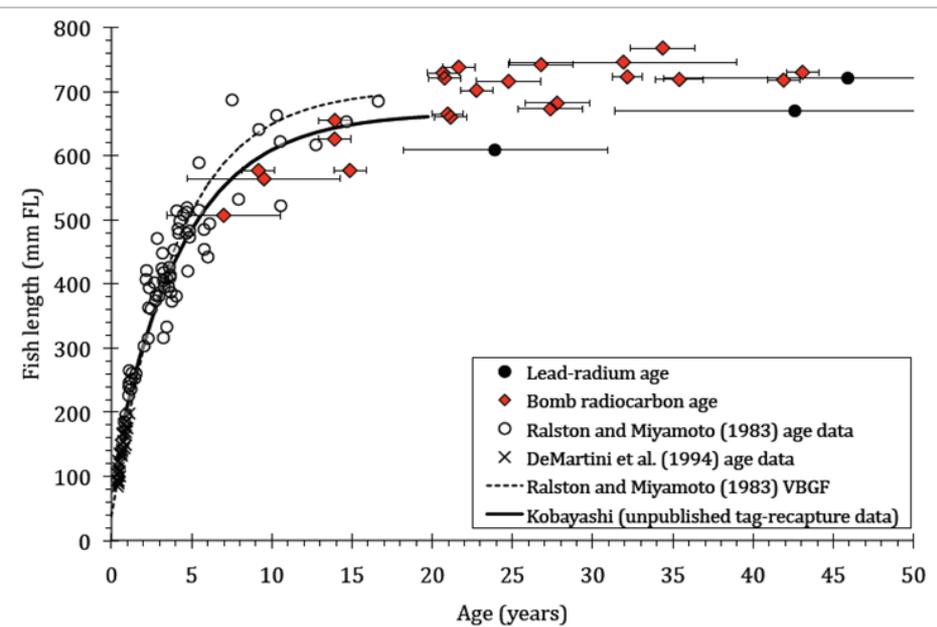
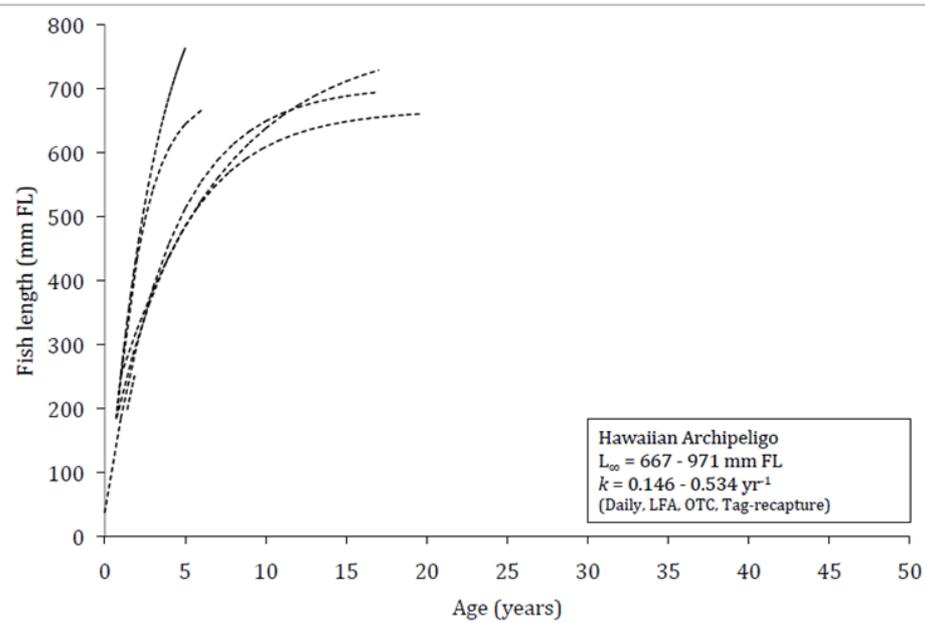
Observation Error

$$I_{i,t} = q_i K P_t \exp(\varepsilon_{i,t})$$

$$\varepsilon_{i,t} \sim N(0, \tau_i^2) \quad i=1; t=1, \dots, N$$



New Information on Growth of Opakapaka (*Pristipomoides filamentosus*) in the Hawaiian Archipelago



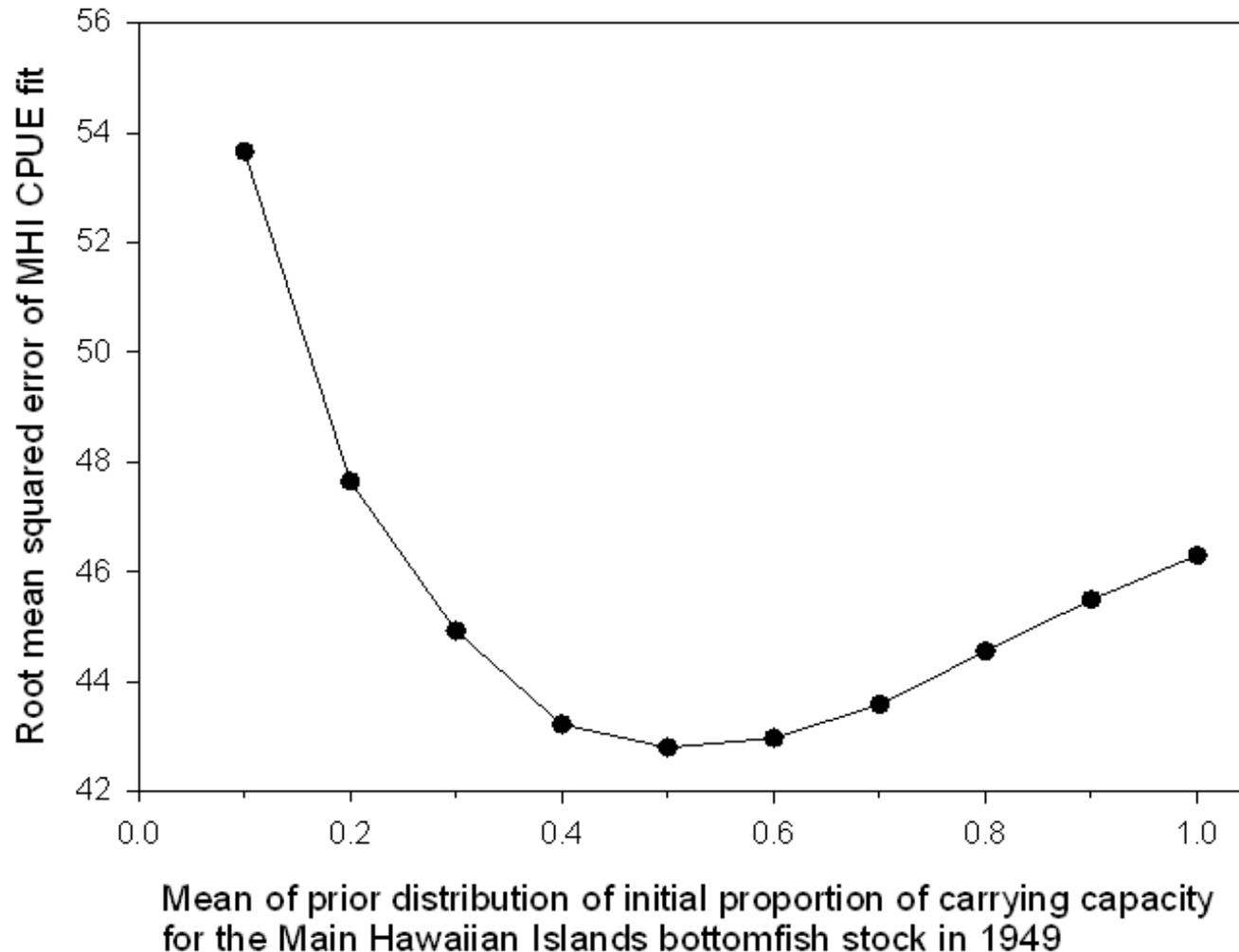
Develop Prior Information on Intrinsic Growth for MHI Deep7 Bottomfish

Deep 7 Species	Productivity Category	Intrinsic Growth Rate r (y^{-1})	von Bertalanffy K (y^{-1})	Fecundity (y^{-1})	Age at Maturity T_{MAT} (y)	Expected Life Span T_{MAX} (y)
Hapuupuu (<i>Epinephelus quernus</i>)	Low	-	0.16-0.23 (Medium)	-	>7 y (Low)	11 y (Low)
Kalekale (<i>Pristipomoides seiboldii</i>)	Medium	-	0.12-0.33 (Medium)	-	-	7 y (Medium)
Opakapaka (<i>Pristipomoides filamentosus</i>)	Low	-	0.15-0.25 (Medium)	$\geq 10^5$ (High)	3.5 y (Medium)	~ 40 y (Low)
Ehu (<i>Etelis carbunculus</i>)	Low	-	0.06-0.19 (Low)	$\geq 10^5$ (High)	-	13 y (Low)
Onaga (<i>Etelis coruscans</i>)	Low	-	0.11-0.27 (Medium)	-	-	13 y (Low)
Lehi (<i>Aphareus rutilans</i>)	Medium	-	0.16 (Medium)	-	-	8 y (Medium)
Gindai (<i>Pristipomoides zonatus</i>)	Medium	-	0.23 (Medium)	-	-	-

$E[r]=0.10$ adapted from Musick (1999) with imputed K values for Hapu, Kalekale, Gindai, and Lehi

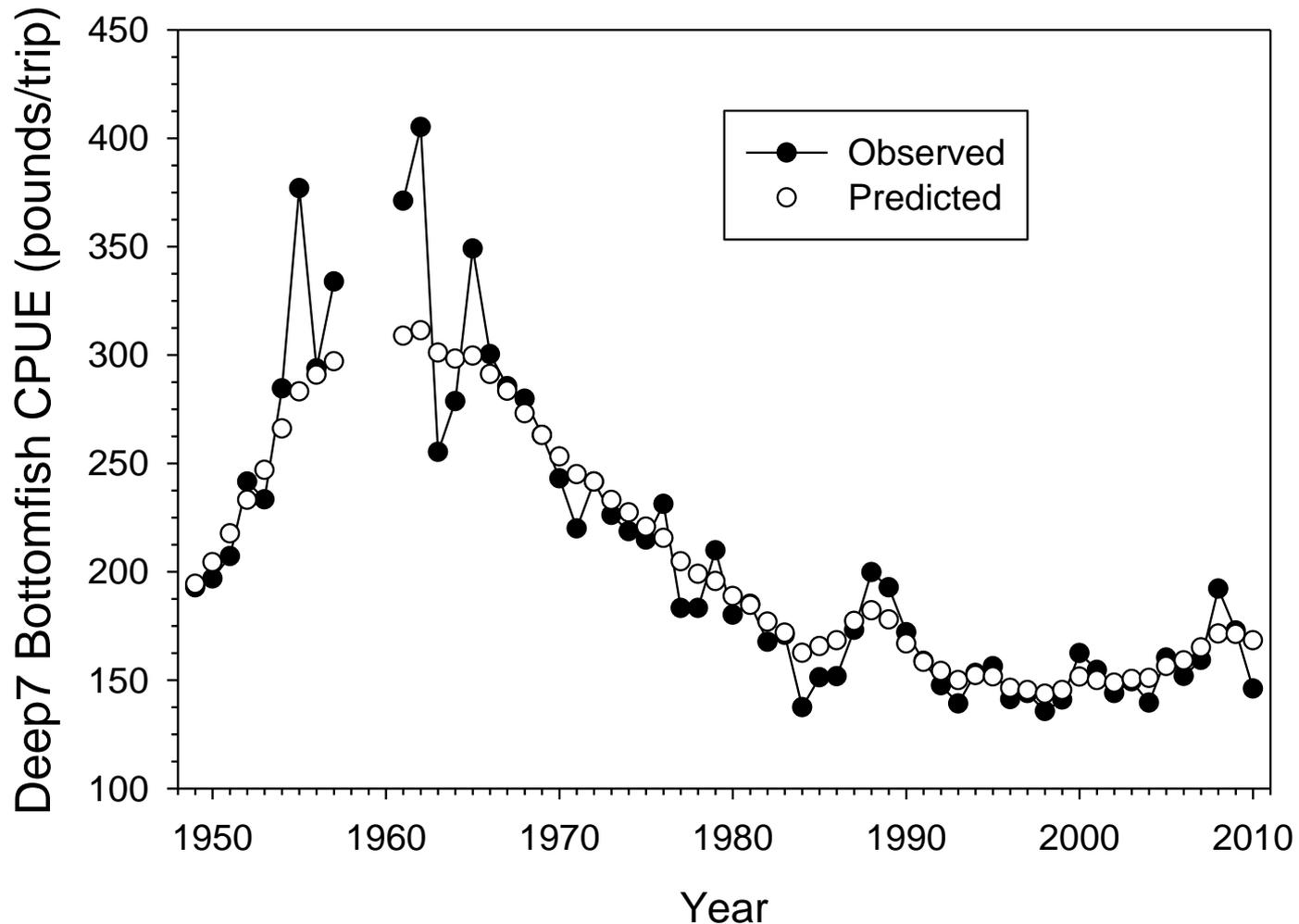
Information on the Prior Mean for the Initial Proportion of MHI Deep7 Bottomfish Carrying Capacity in FY 1949

Goodness-of-fit of predicted MHI CPUE as a function of the prior mean for the initial proportion of carrying capacity in the MHI under catch Scenario II



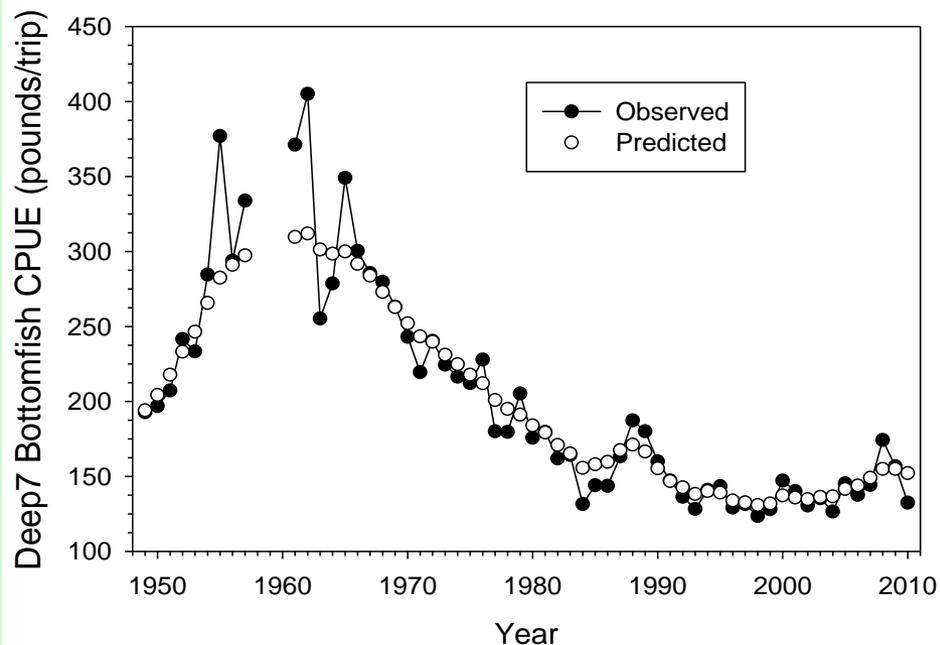
Base Case Model Fit to Bottomfish CPUE

Observed standardized CPUE Scenario I of Deep7 bottomfish versus predicted CPUE by fishing year, 1949-2010, under Catch Scenario II

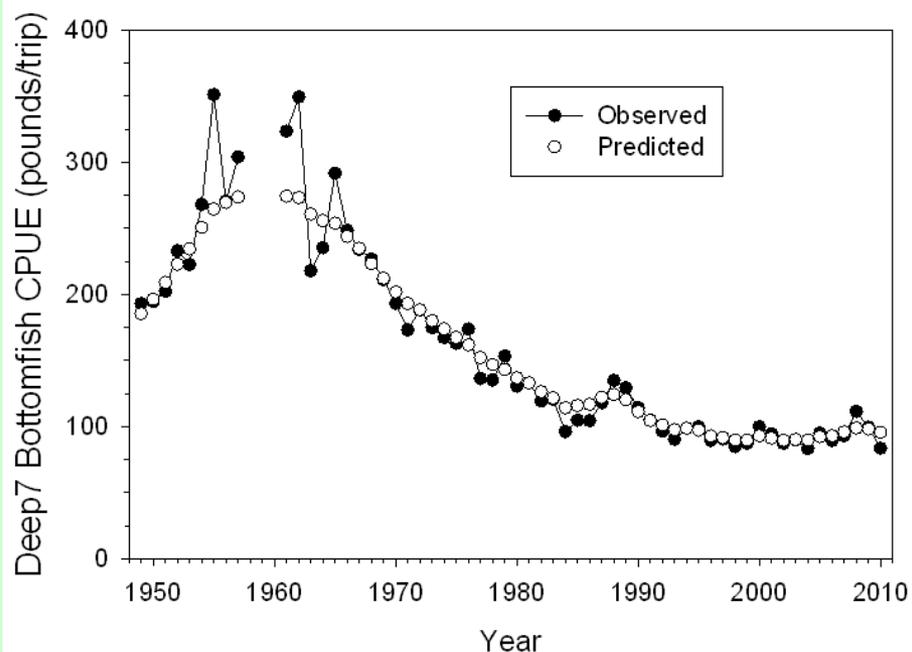


Test Impacts of CPUE Uncertainty: Sensitivity Analysis With CPUE Scenarios II and III

Observed standardized CPUE Scenario II of Deep7 bottomfish versus predicted CPUE by fishing year, 1949-2010, under Catch Scenario II

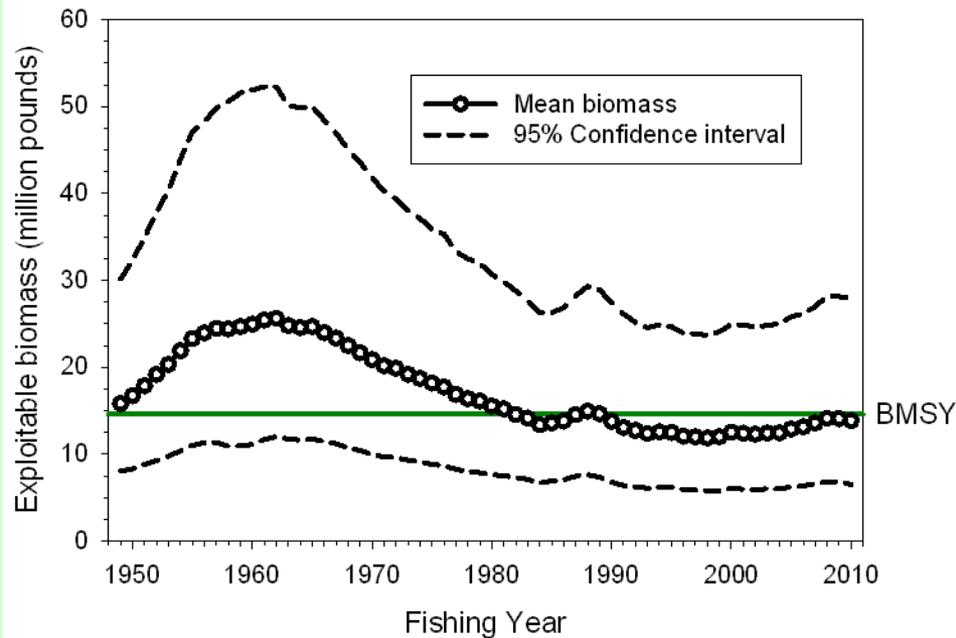


Observed standardized CPUE Scenario III of Deep7 bottomfish versus predicted CPUE by fishing year, 1949-2010, under Catch Scenario II

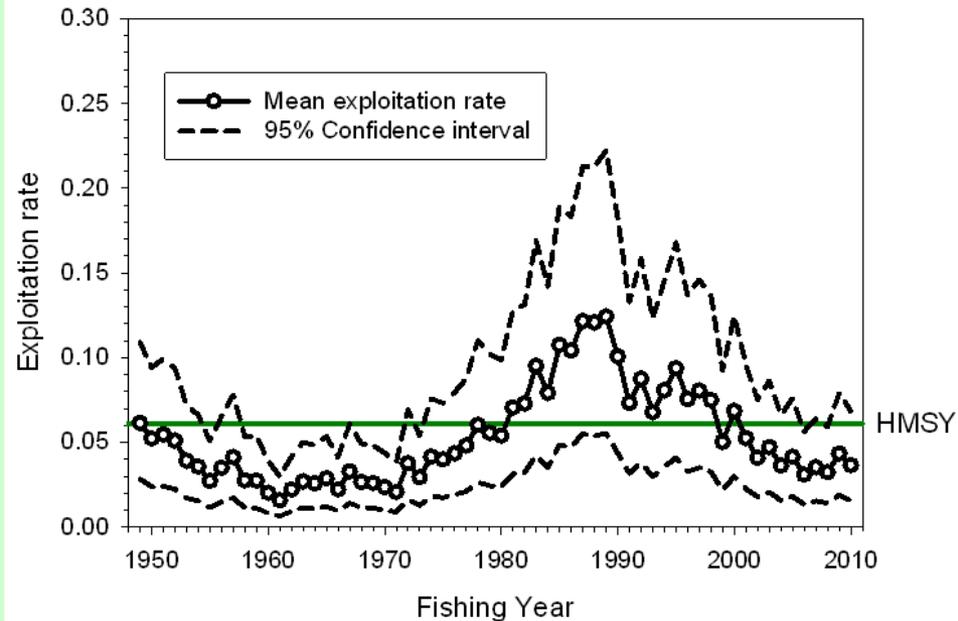


Estimates of MHI Deep7 Bottomfish Exploitable Biomass and Harvest Rate

Estimated deep7 bottomfish biomass under Catch Scenario II and CPUE Scenario I, 1949-2010

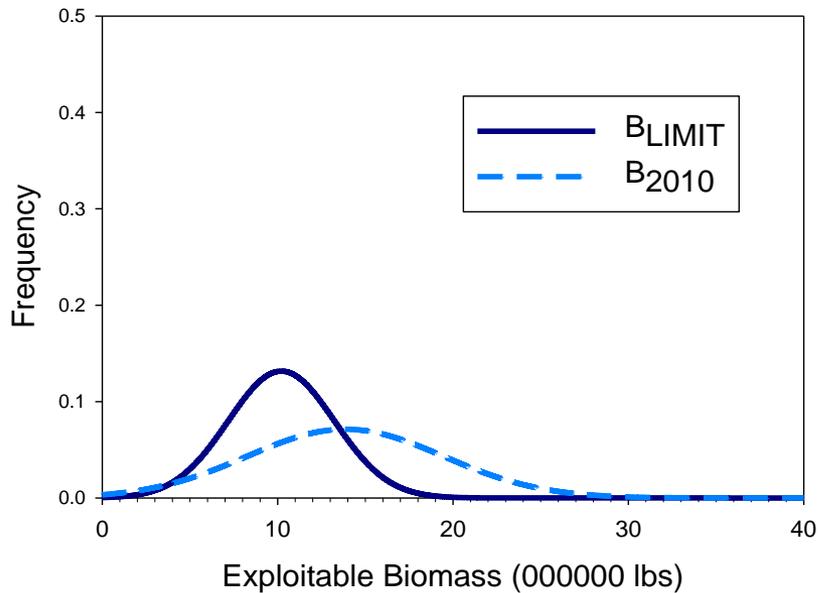


Estimated deep7 bottomfish exploitation rate under Catch Scenario II and CPUE Scenario I, 1949-2010

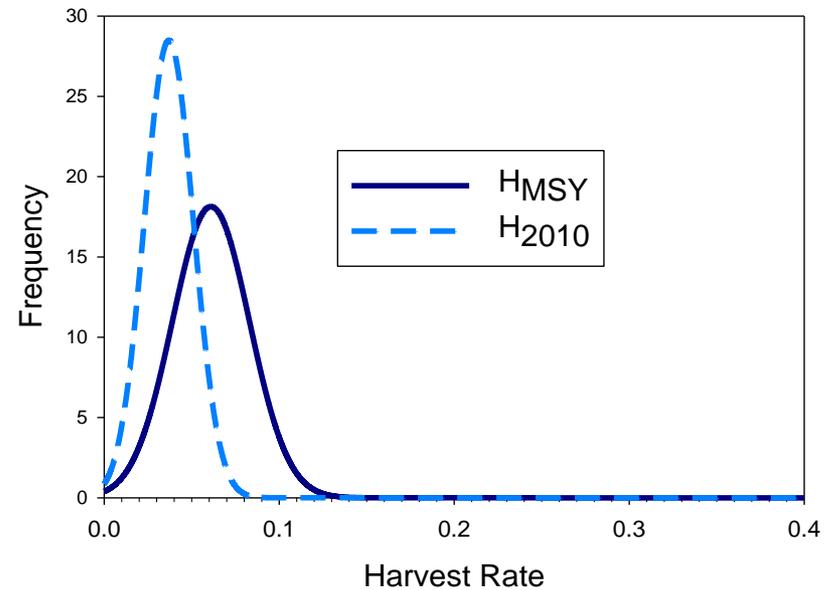


Estimate of 2010 Exploitable Biomass and Harvest Rate and Overfishing Level Distributions

Baseline Catch Scenario II and CPUE Scenario I: Distributions of Estimates of Exploitable Biomass in 2010 and Overfished Limit for Deep7 Hawaii Bottomfish

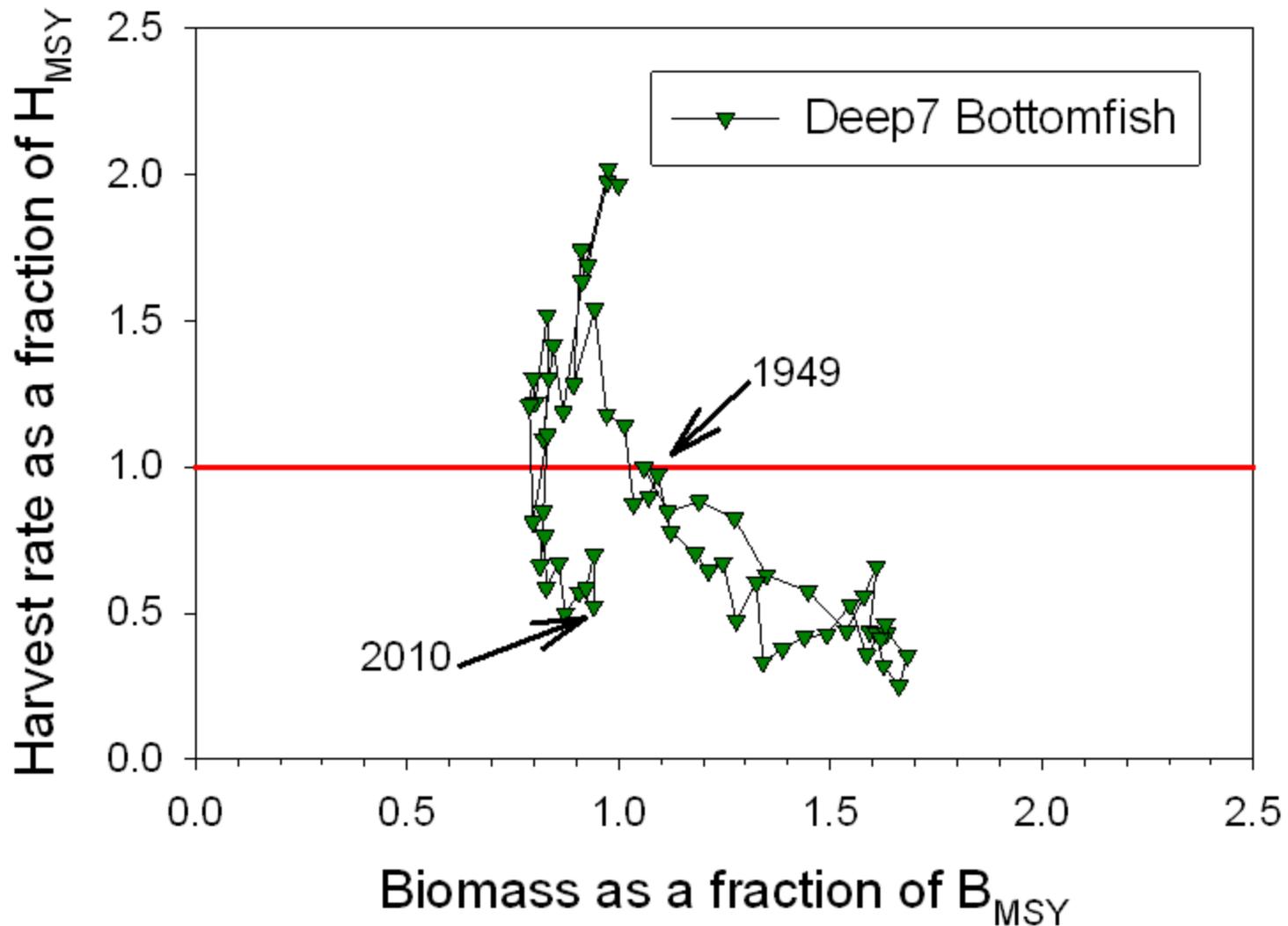


Baseline Catch Scenario II and CPUE Scenario I: Distributions of Estimates of Harvest Rate in 2010 and Overfishing Limit for Deep7 Hawaii Bottomfish

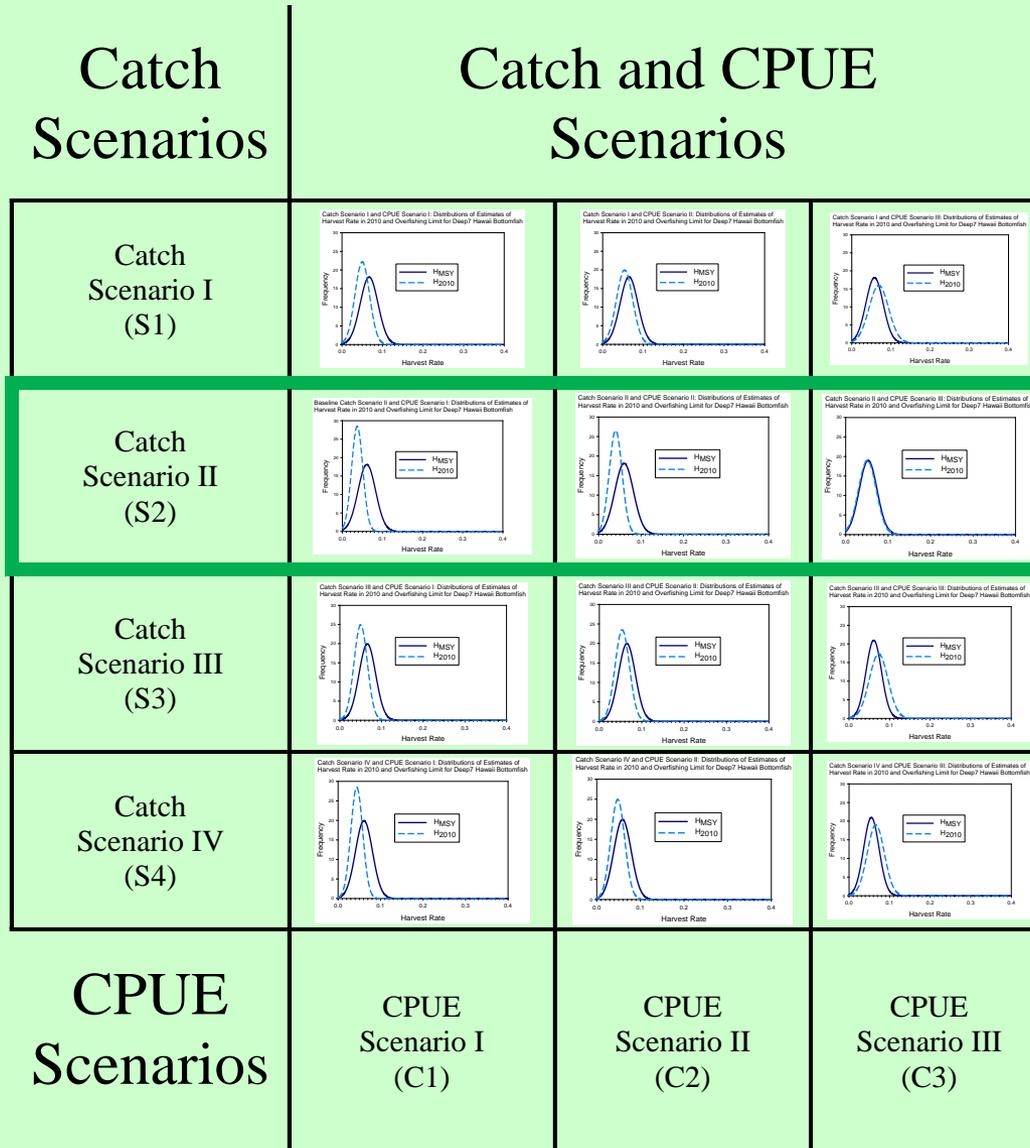


Kobe Plot

Estimated deep7 bottomfish stock status
under Catch Scenario II and CPUE Scenario I, 1949-2010

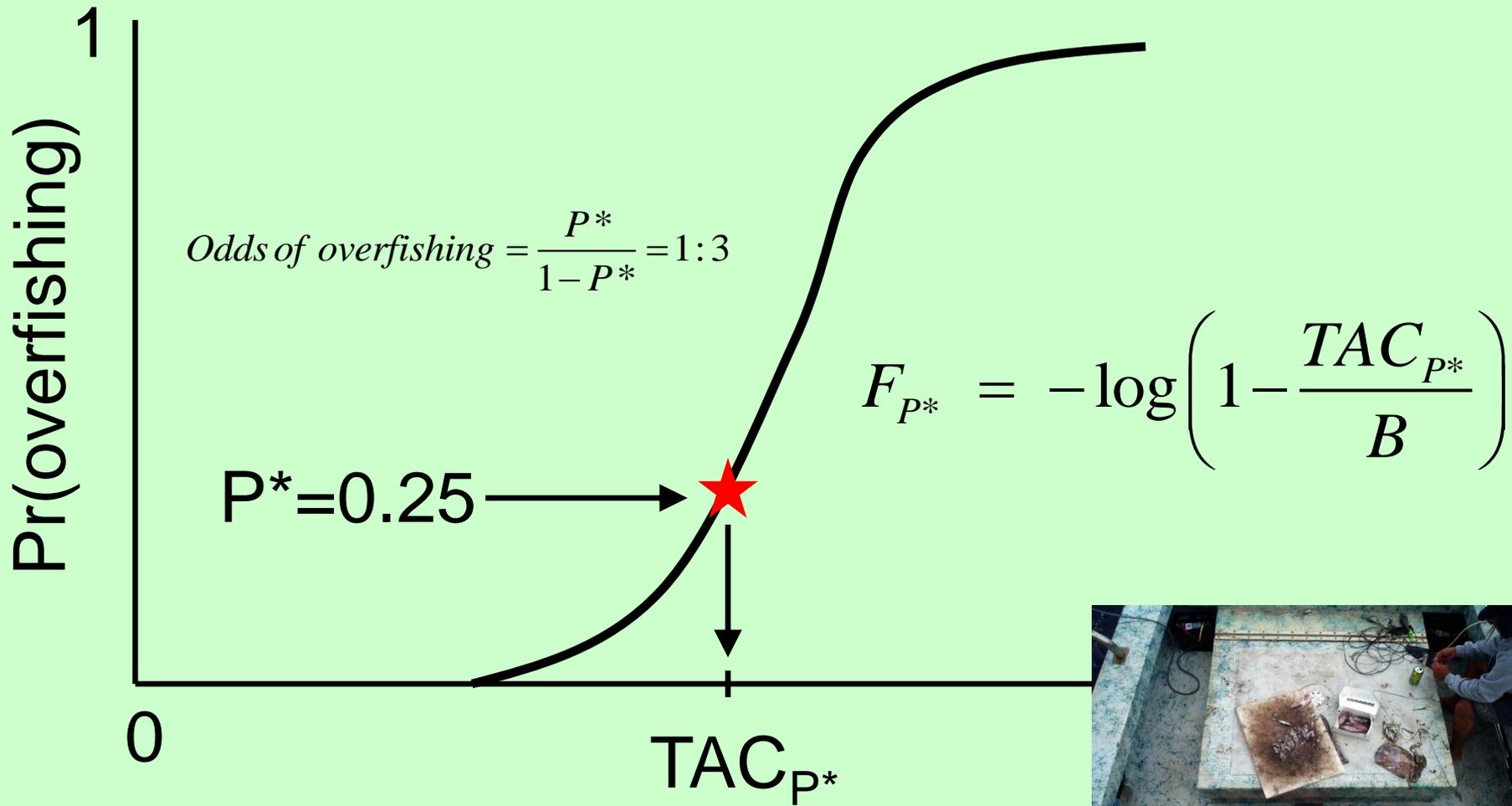


Sensitivity analyses of overfishing status of Deep7 Hawaii bottomfish in 2010

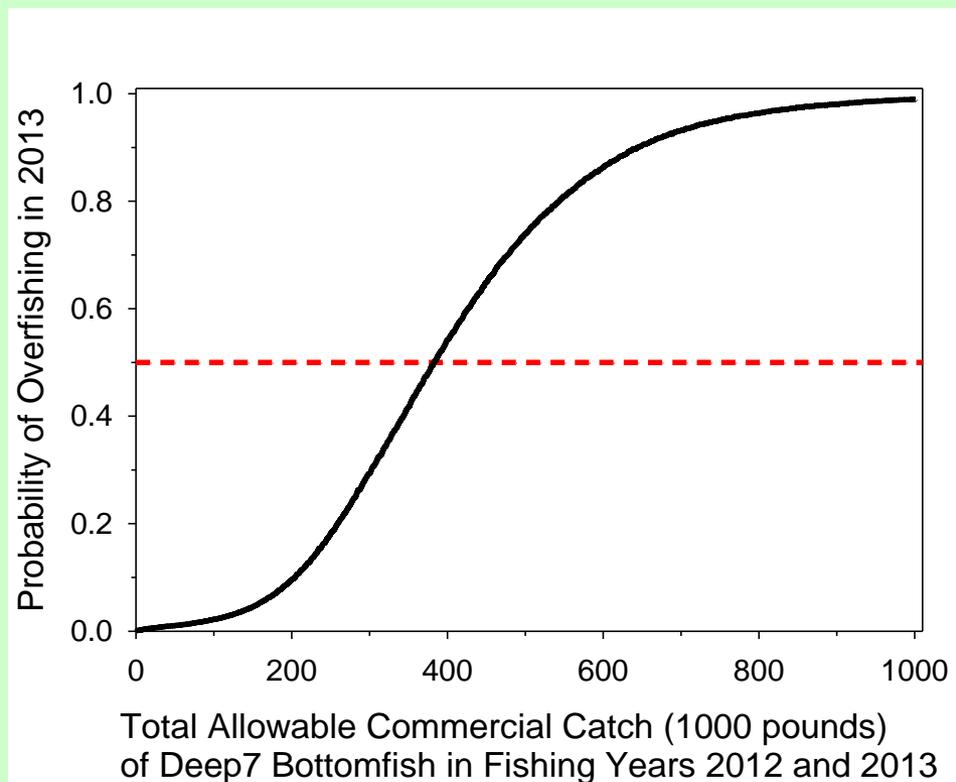
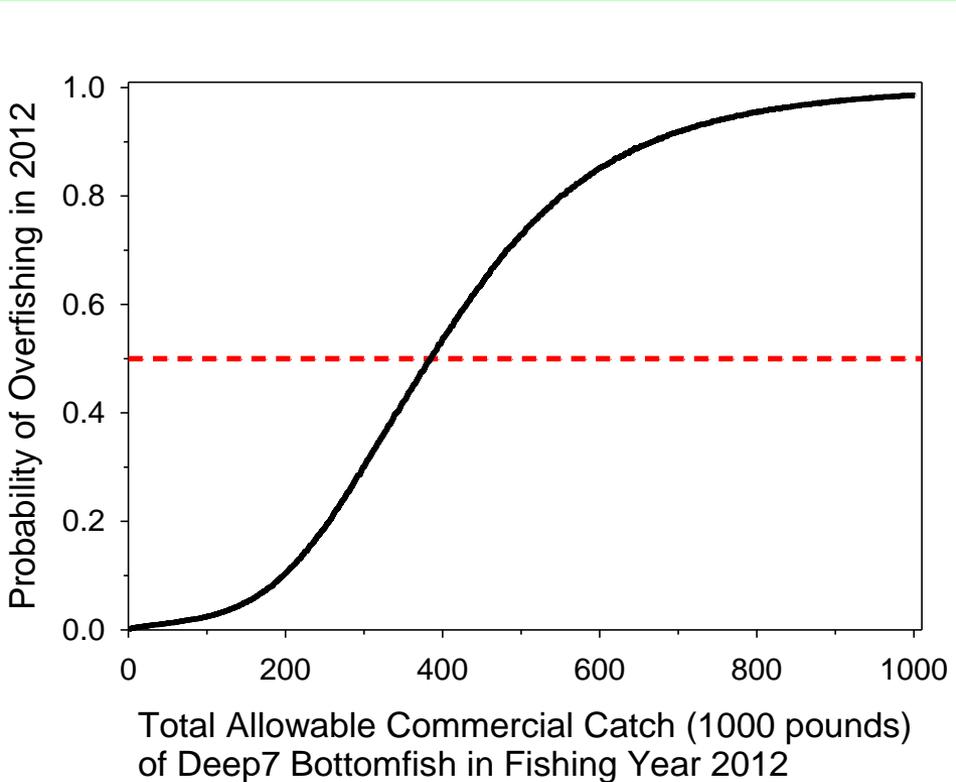


Projections for the Probability of Overfishing P^*

Example: Choose $P^* = 0.25$



P* Projections for 2012 and 2013



Decision Table with $P^* = 0.5$

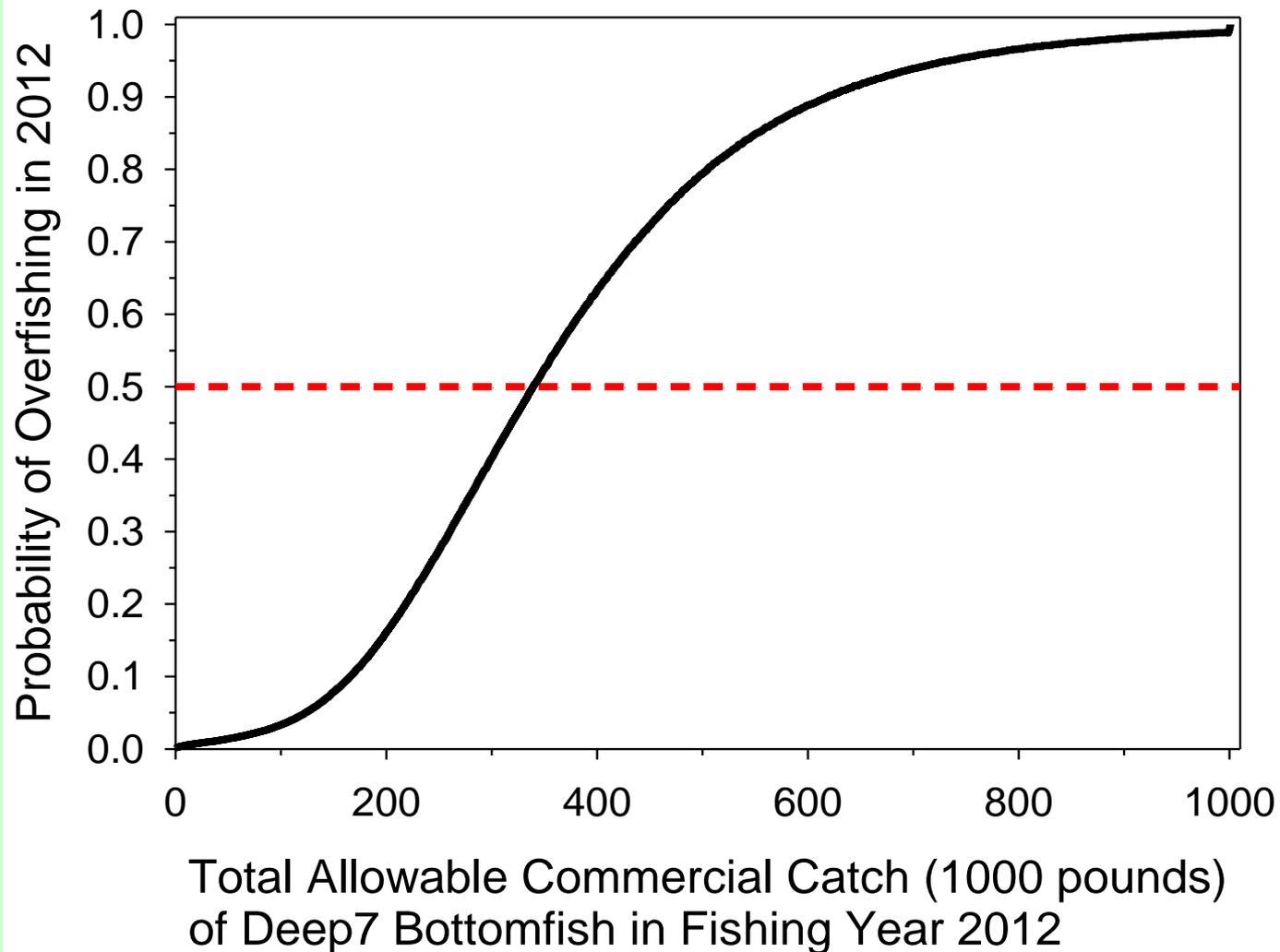
$P^* = 0.5$	True State of Nature		
Model Catch and CPUE Scenario Used to Set TAC	Catch II CPUE I	Catch II CPUE II	Catch II CPUE III
Catch II CPUE I TAC = 383	$\Pr(H_{2012} > H_{MSY}) = 0.50$ $\Pr(H_{2013} > H_{MSY}) = 0.50$ $B_{2013}/B_{MSY} = 0.98$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.12$	$\Pr(H_{2012} > H_{MSY}) = 0.61$ $\Pr(H_{2013} > H_{MSY}) = 0.60$ $B_{2013}/B_{MSY} = 0.89$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.20$	$\Pr(H_{2012} > H_{MSY}) = 0.88$ $\Pr(H_{2013} > H_{MSY}) = 0.88$ $B_{2013}/B_{MSY} = 0.62$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.66$
Catch II CPUE II TAC = 339	$\Pr(H_{2012} > H_{MSY}) = 0.40$ $\Pr(H_{2013} > H_{MSY}) = 0.39$ $B_{2013}/B_{MSY} = 0.99$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.12$	$\Pr(H_{2012} > H_{MSY}) = 0.50$ $\Pr(H_{2013} > H_{MSY}) = 0.49$ $B_{2013}/B_{MSY} = 0.90$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.19$	$\Pr(H_{2012} > H_{MSY}) = 0.82$ $\Pr(H_{2013} > H_{MSY}) = 0.81$ $B_{2013}/B_{MSY} = 0.62$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.65$
Catch II CPUE III TAC = 227	$\Pr(H_{2012} > H_{MSY}) = 0.15$ $\Pr(H_{2013} > H_{MSY}) = 0.14$ $B_{2013}/B_{MSY} = 1.00$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.10$	$\Pr(H_{2012} > H_{MSY}) = 0.20$ $\Pr(H_{2013} > H_{MSY}) = 0.19$ $B_{2013}/B_{MSY} = 0.91$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.17$	$\Pr(H_{2012} > H_{MSY}) = 0.50$ $\Pr(H_{2013} > H_{MSY}) = 0.48$ $B_{2013}/B_{MSY} = 0.64$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.62$

Alternative States of Nature: Scenario Probabilities

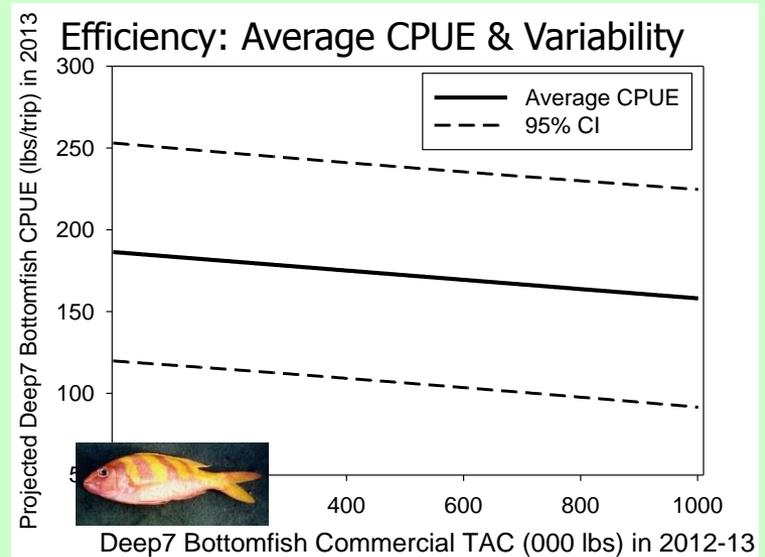
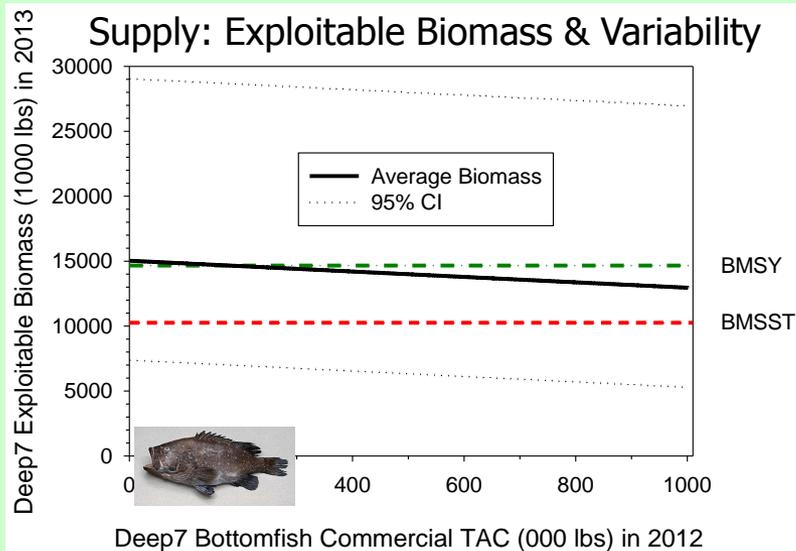
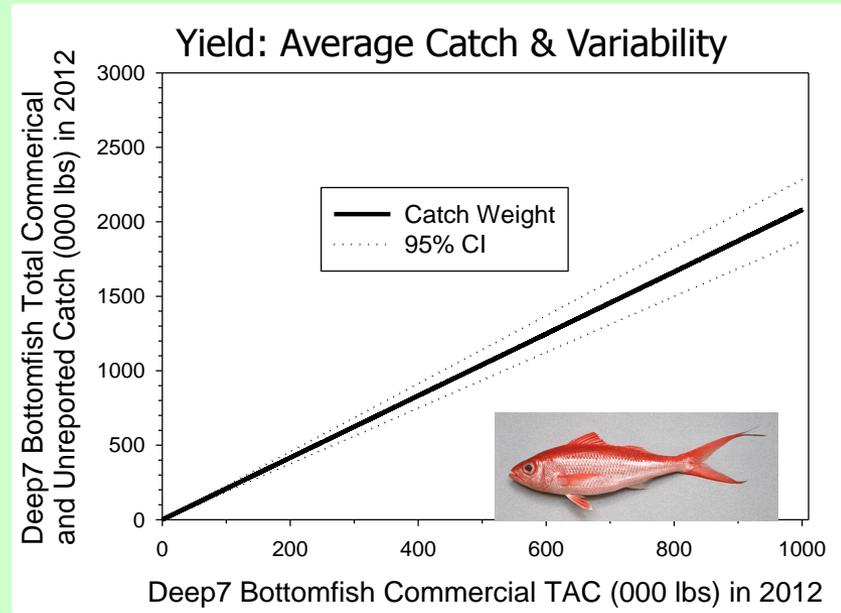
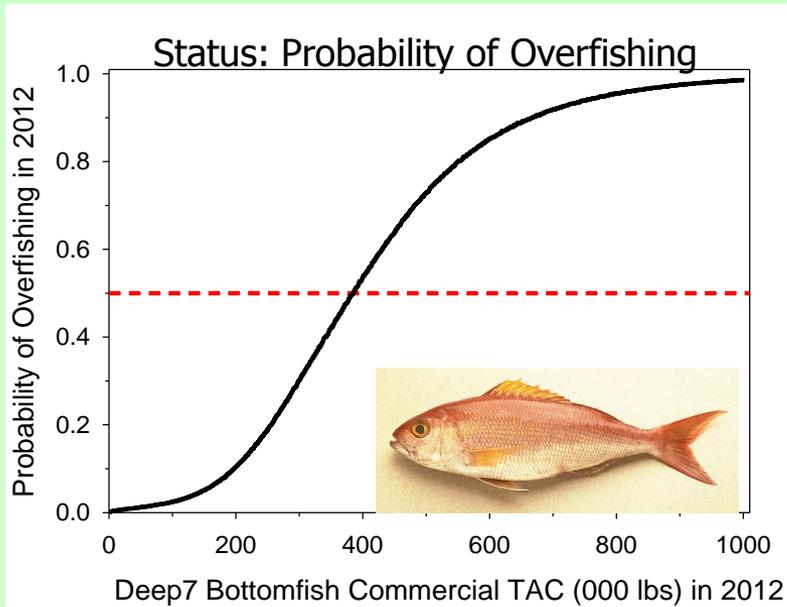
Probabilities of Catch Scenarios $P(S)$	Joint Probabilities of Catch and CPUE Scenarios $P(S) \cdot P(C)$		
Catch Scenario I $P(S1) = 1/20$	25/1000	20/1000	5/1000
Catch Scenario II $P(S2) = 4/5$	400/1000	320/1000	80/1000
Catch Scenario III $P(S3) = 1/10$	50/1000	40/1000	10/1000
Catch Scenario IV $P(S4) = 1/20$	25/1000	20/1000	5/1000
Probabilities of CPUE Scenarios $P(C)$	CPUE Scenario I $P(C1) = 1/2$	CPUE Scenario II $P(C2) = 2/5$	CPUE Scenario III $P(C3) = 1/10$

Model-Averaged P^* Projection

Scenario-Averaged Probability of Overfishing Deep7 Hawaii Bottomfish in Fishing Year 2012 as a Function of the Commercial TAC



Multivariate Benefit Streams for Forecasts: Hawaii Bottomfish



Modeling and Forecasting Improvements With Data Limitations

- **Improved Data Collection (both timeliness and data types)**
 - ✓ Increased sample sizes of input data, e.g., bottomfish biosampling at Honolulu auction
 - ✓ New surveys, e.g. fishery independent surveys and monitoring
 - ✓ More timely data for improving modeling and forecasting, e.g. online logbook reporting
- **Improved Monitoring of the Fishery System**
 - Realize unaccounted uncertainty, e.g., HMRFSS recreational catch survey
 - Better practical understanding of what works and what doesn't, e.g. BRFA research
- **Modeling Improvements**
 - ❑ Use model ensembles, model-averaged P^* projections
 - ❑ Improved predictive accuracy from models, e.g., including vessel effects after 1993
 - ❑ Improved use of environmental linkages, e.g. SOI effects on catchability
 - ❑ Improved use of socio-economic linkages, e.g. fleet behavior with wind patterns
 - ❑ Improved treatment of uncertainty in parameter values, e.g., Bayesian data analyses

~ Thanks and Mahalo !

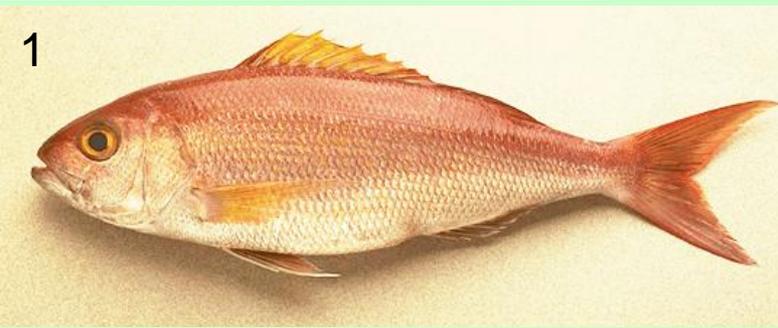


Auxiliary Slides

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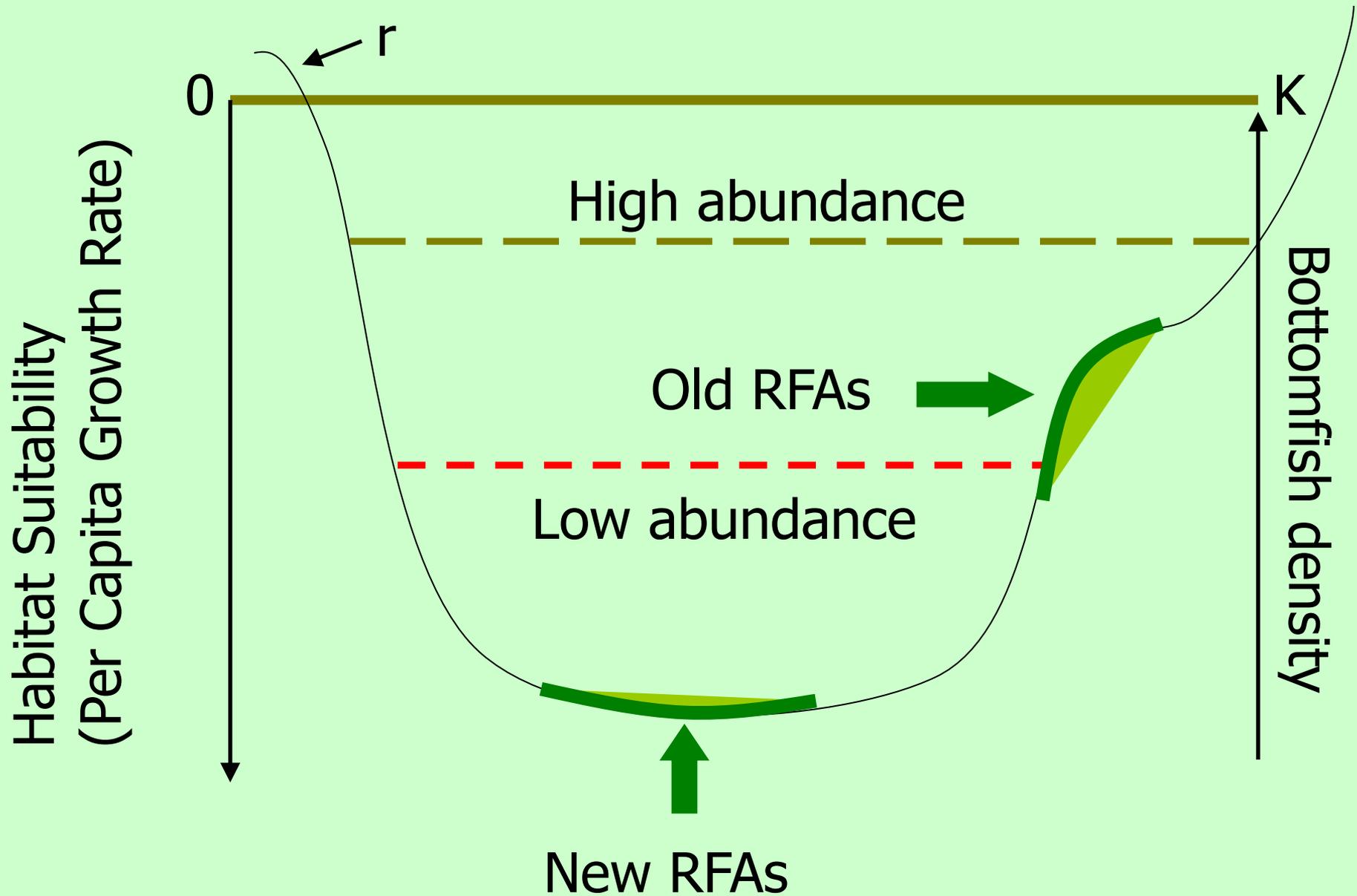


Deep 7 bottomfish species are:

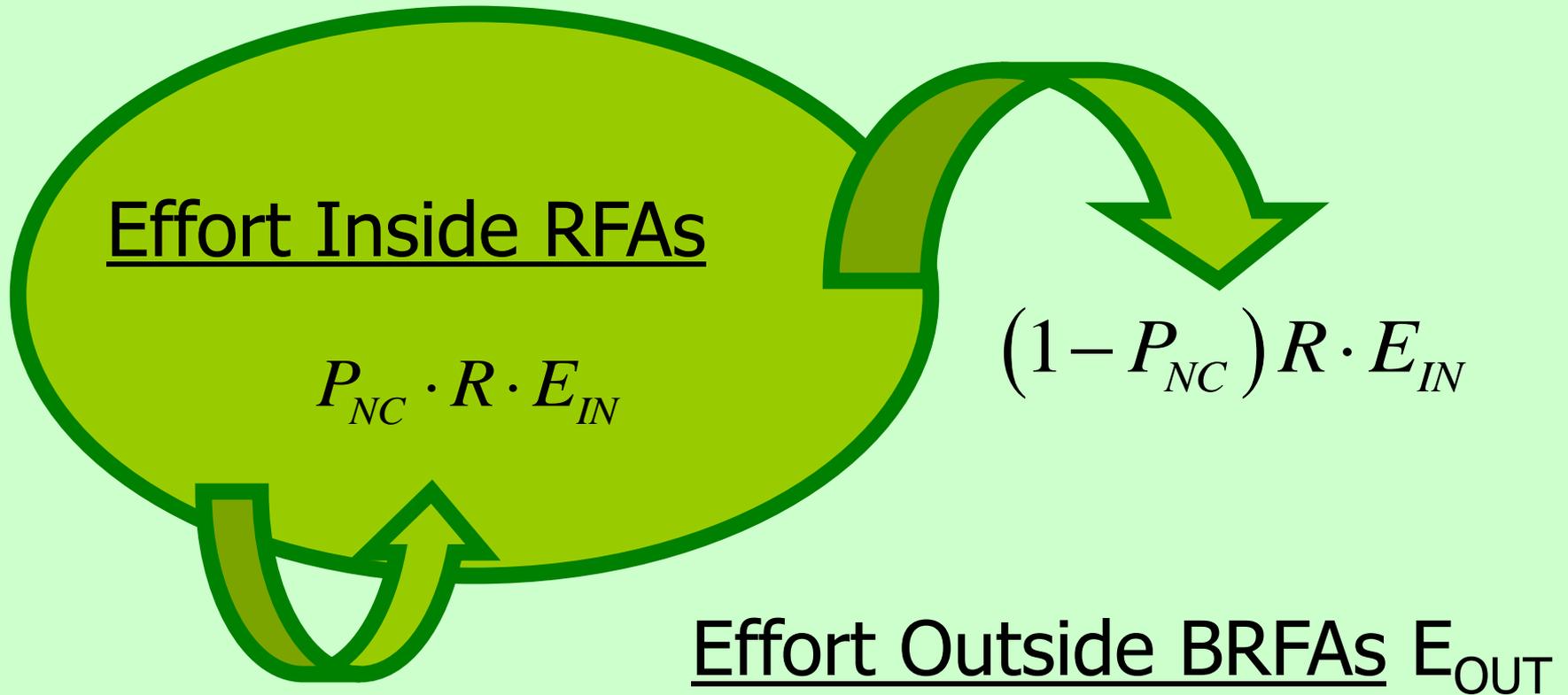
- (1) Opakapaka (*Pristipomoides filamentosus*);
- (2) Kalekale (*Pristipomoides sieboldii*);
- (3) Lehi (*Aphareus rutilans*);
- (4) Gindai (*Pristipomoides zonatus*);
- (5) Onaga (*Etelis coruscans*);
- (6) Ehu (*Etelis carbunculus*);
- (7) Hapuupuu (*Epinephelus quernus*).



Habitat Basin Model to Assess Effects of BRFA's



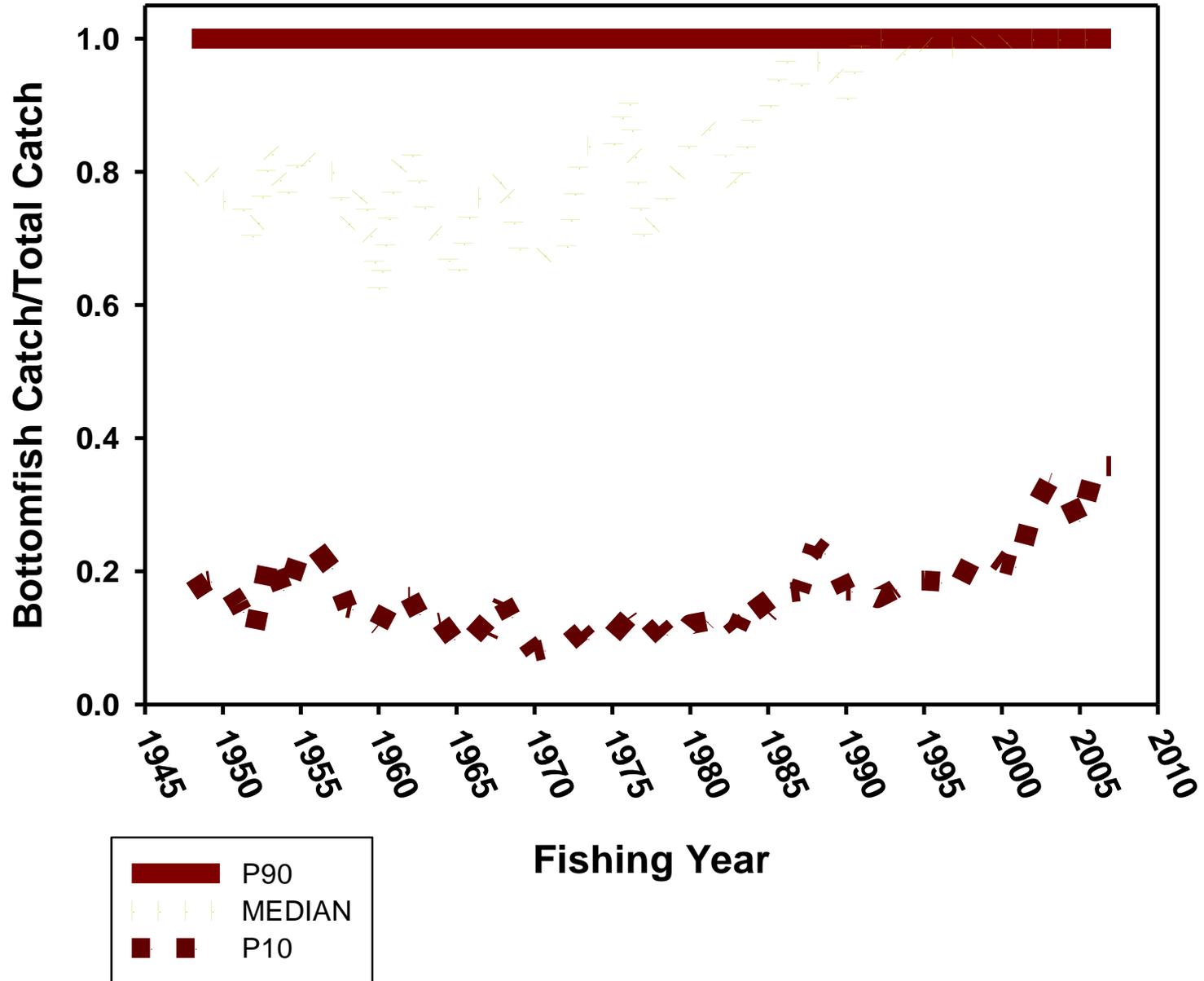
Redistribution of Fishing Effort Inside BRFAs And Noncompliance with BRFAs



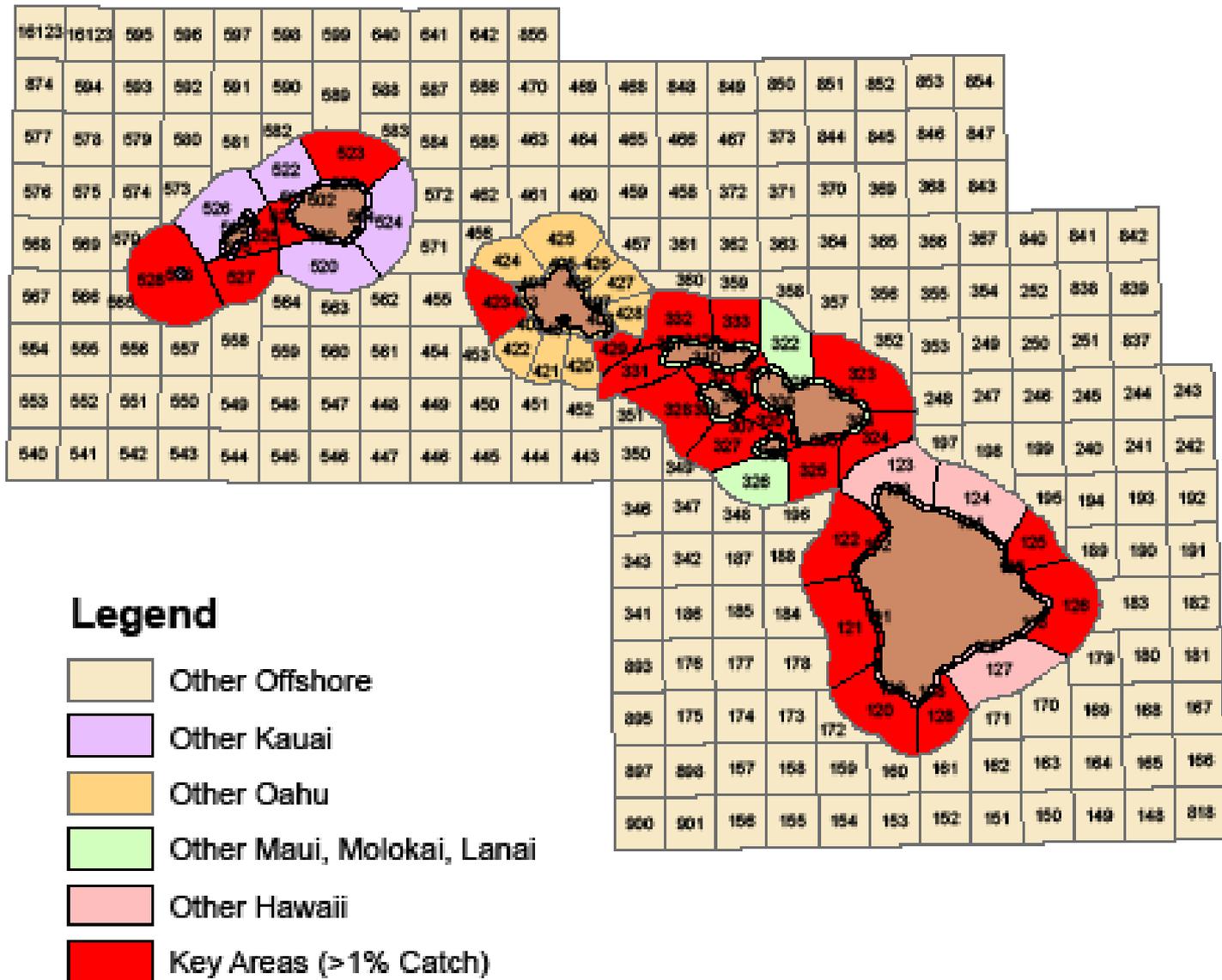
Total Fishing Mortality

$$F = -\ln \left(1 - \left(\frac{B_{IN}}{B} \left(1 - e^{-q_{IN} \cdot R \cdot P_{NC} \cdot E_{IN}} \right) + \frac{B_{OUT}}{B} \left(1 - e^{-q_{OUT} (E_{OUT} + R \cdot (1 - P_{NC}) \cdot E_{IN})} \right) \right) \right)$$

Bottomfish Catch Ratio by Fishing Year

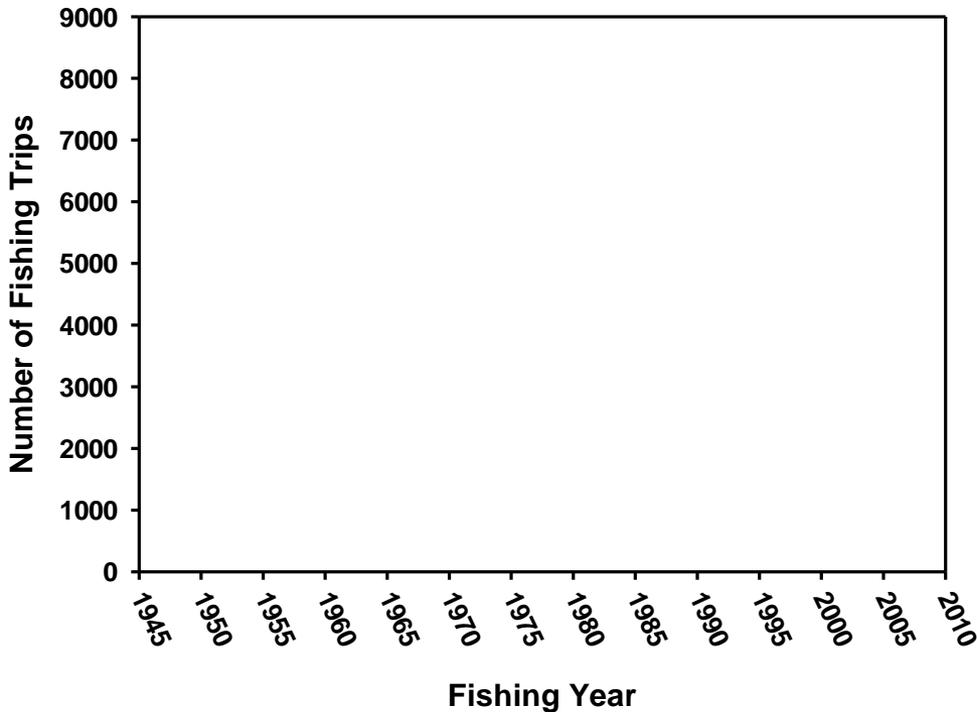


HDAR fishing areas used as factors in GLM

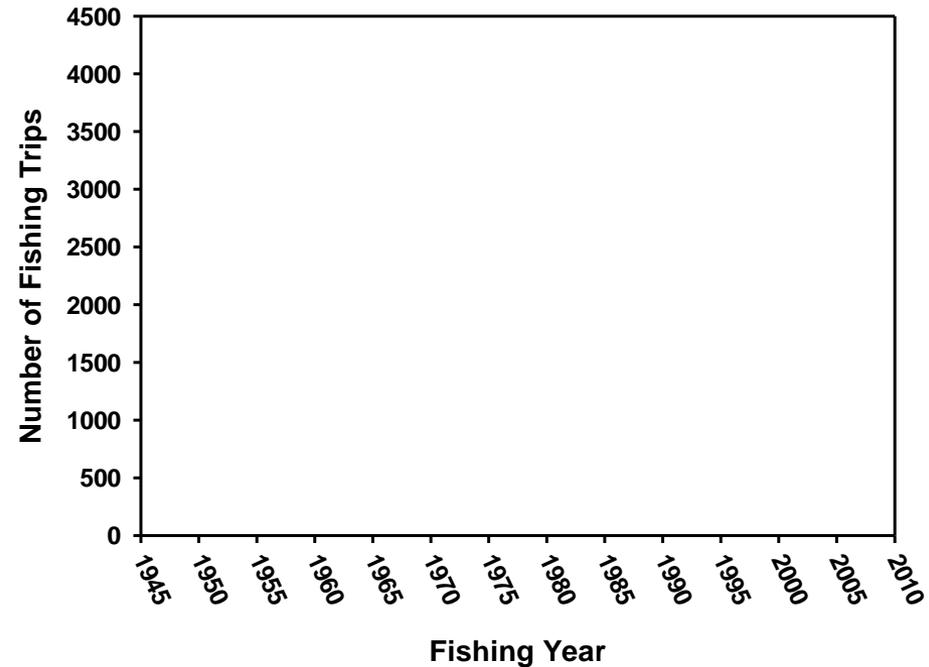


MHI Bottomfish Effort Trends

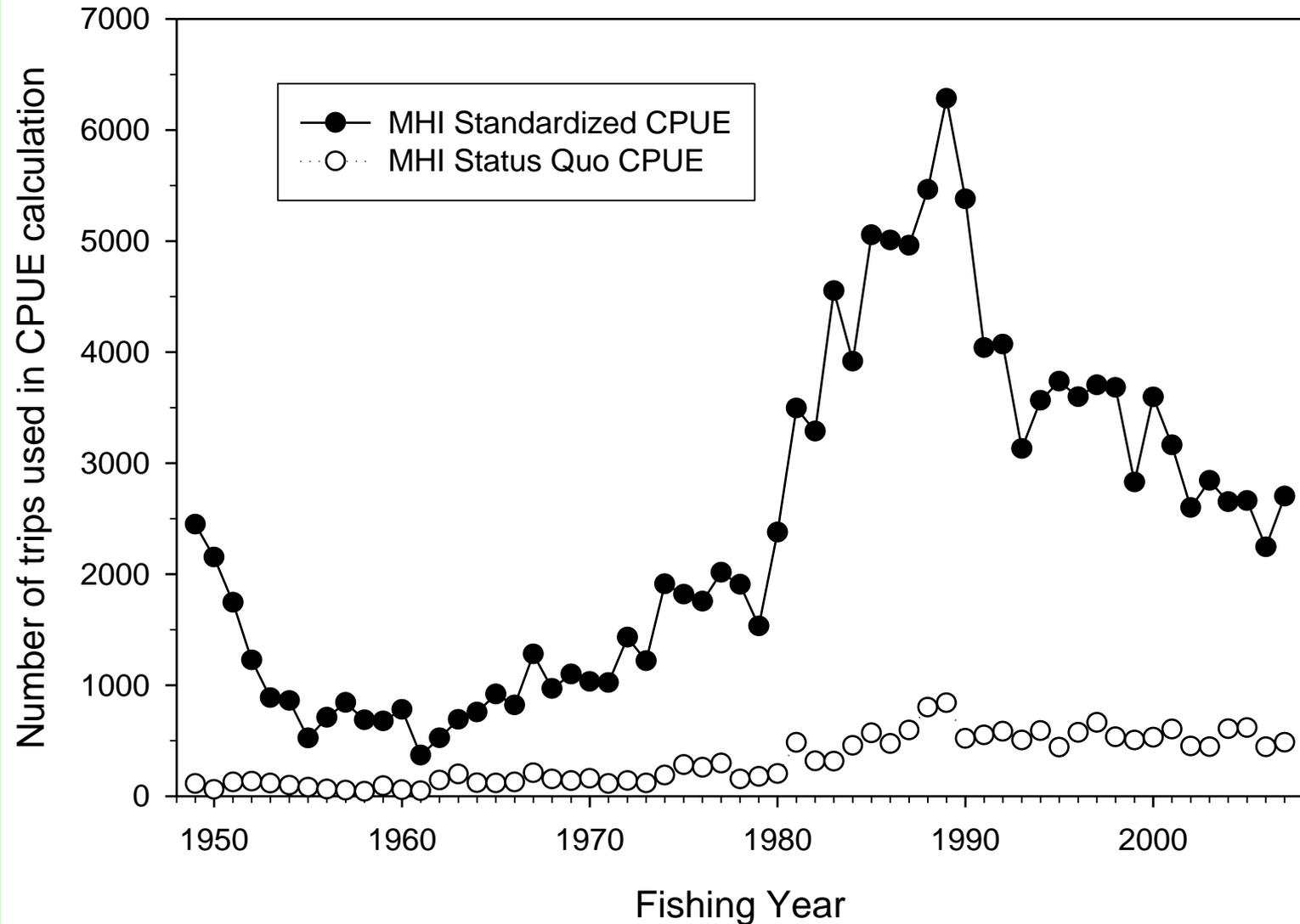
Number of Bottomfish Fishing Trips by Year



Number of Bottomfish Fishing Trips with Non-Bottomfish Catch by Year

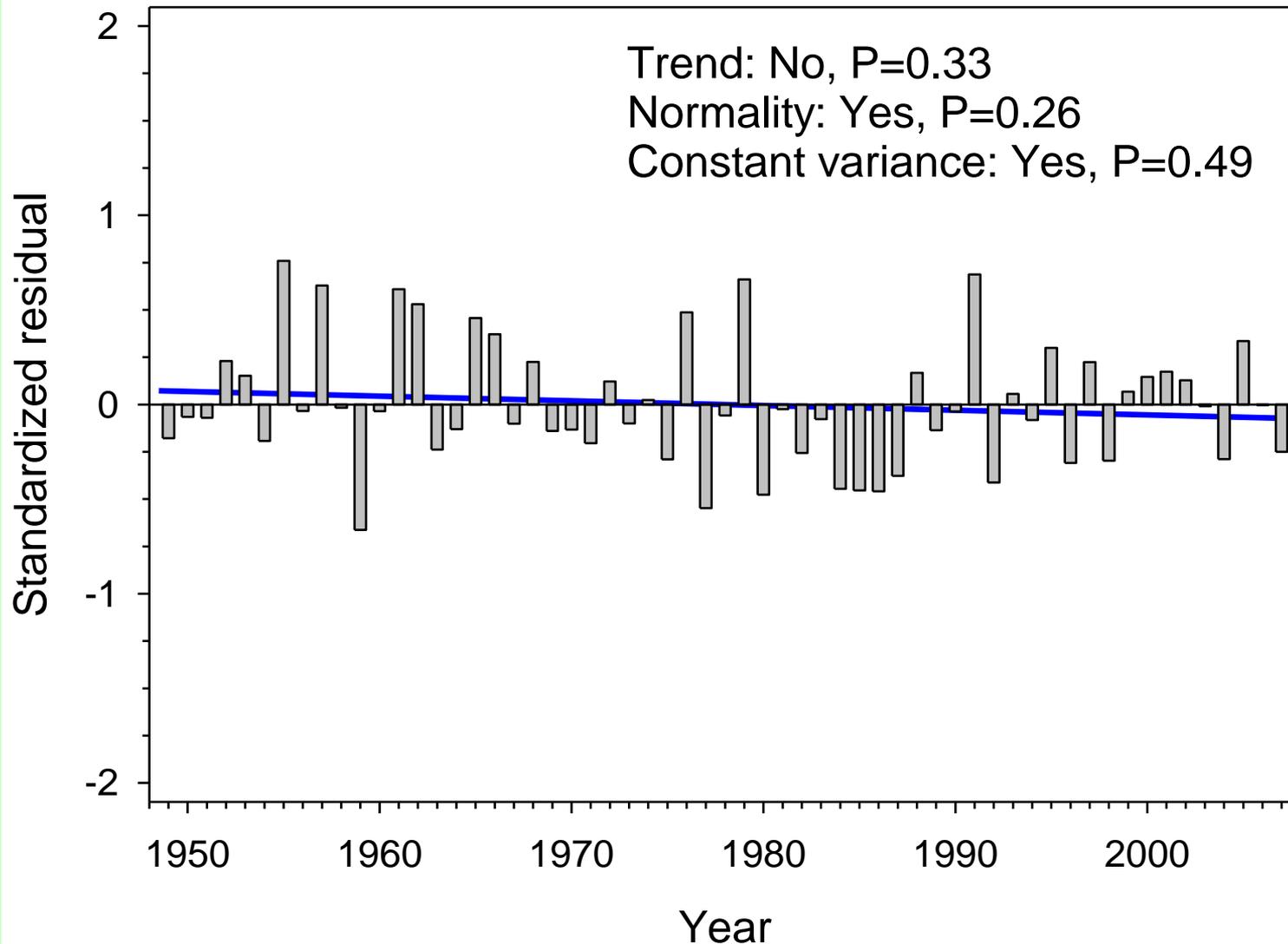


Comparison of input data: Trips used for standardized CPUE versus previous method to compute CPUE



Results: Standardized Residuals for MHI CPUE

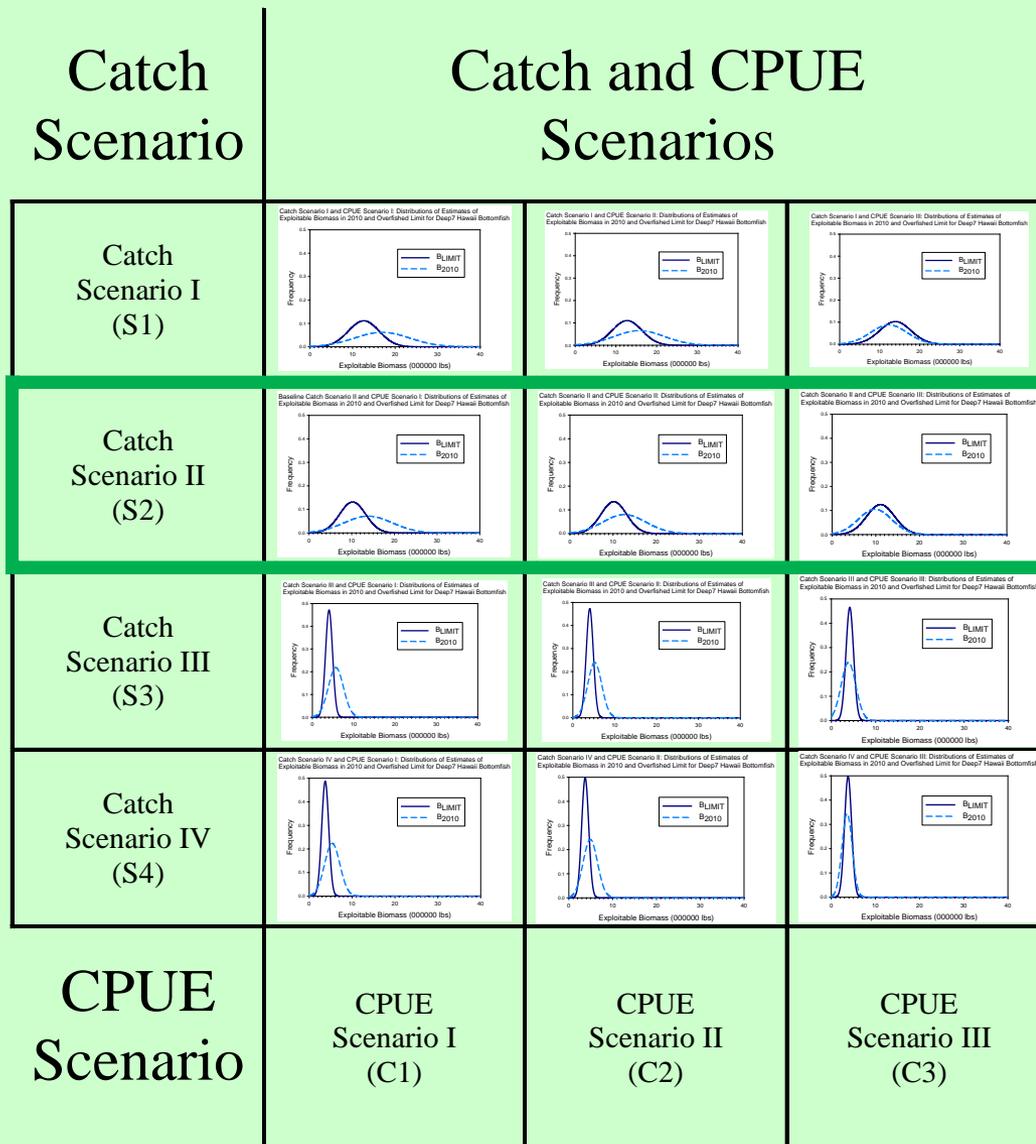
Standardized log-scale residuals of the production model fit to standardized CPUE in the Main Hawaiian Islands by fishing year, 1949-2007



Catch Scenario II and CPUE Scenario I

Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	11	0	1.05	0.92
0.05	147	0.02	1.03	0.91
0.10	197	0.09	1.02	0.90
0.15	229	0.14	1.02	0.90
0.20	255	0.19	1.01	0.89
0.25	277	0.24	1.01	0.89
0.30	299	0.29	1.01	0.89
0.35	319	0.34	1.00	0.88
0.40	341	0.39	1.00	0.88
0.45	361	0.45	1.00	0.88
0.50	383	0.50	0.99	0.88
0.55	407	0.56	0.99	0.87
0.60	429	0.60	0.99	0.87
0.65	455	0.66	0.98	0.87
0.70	481	0.71	0.98	0.86
0.75	513	0.76	0.97	0.86
0.80	549	0.81	0.97	0.85
0.85	597	0.86	0.96	0.84
0.90	665	0.91	0.95	0.83
0.95	783	0.96	0.93	0.81
0.99	1001	0.99	0.90	0.77

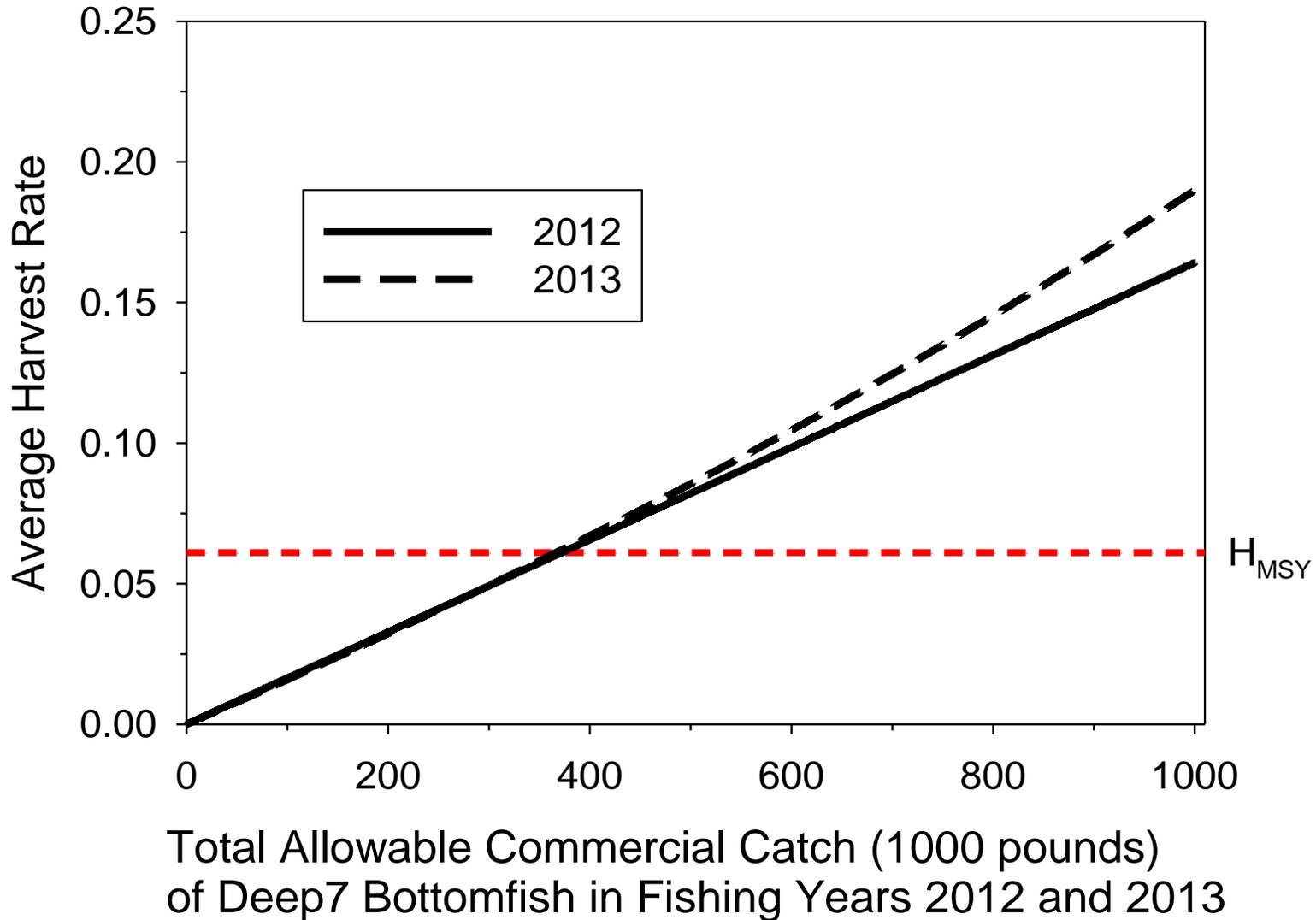
Sensitivity analyses of overfished status of Deep7 Hawaii bottomfish in 2010



Decision Table with $P^*=0.25$

$P^* = 0.25$	True State of Nature		
Model Catch and CPUE Scenario Used to Set TAC	Catch II CPUE I	Catch II CPUE II	Catch II CPUE III
Catch II CPUE I TAC = 277	$\Pr(H_{2012} > H_{MSY}) = 0.25$ $\Pr(H_{2013} > H_{MSY}) = 0.24$ $B_{2013}/B_{MSY} = 1.00$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.11$	$\Pr(H_{2012} > H_{MSY}) = 0.33$ $\Pr(H_{2013} > H_{MSY}) = 0.32$ $B_{2013}/B_{MSY} = 0.91$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.18$	$\Pr(H_{2012} > H_{MSY}) = 0.67$ $\Pr(H_{2013} > H_{MSY}) = 0.65$ $B_{2013}/B_{MSY} = 0.62$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.63$
Catch II CPUE II TAC = 249	$\Pr(H_{2012} > H_{MSY}) = 0.19$ $\Pr(H_{2013} > H_{MSY}) = 0.18$ $B_{2013}/B_{MSY} = 1.00$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.11$	$\Pr(H_{2012} > H_{MSY}) = 0.25$ $\Pr(H_{2013} > H_{MSY}) = 0.24$ $B_{2013}/B_{MSY} = 0.91$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.18$	$\Pr(H_{2012} > H_{MSY}) = 0.58$ $\Pr(H_{2013} > H_{MSY}) = 0.56$ $B_{2013}/B_{MSY} = 0.64$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.63$
Catch II CPUE III TAC = 163	$\Pr(H_{2012} > H_{MSY}) = 0.06$ $\Pr(H_{2013} > H_{MSY}) = 0.06$ $B_{2013}/B_{MSY} = 1.01$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.10$	$\Pr(H_{2012} > H_{MSY}) = 0.08$ $\Pr(H_{2013} > H_{MSY}) = 0.08$ $B_{2013}/B_{MSY} = 0.92$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.16$	$\Pr(H_{2012} > H_{MSY}) = 0.25$ $\Pr(H_{2013} > H_{MSY}) = 0.24$ $B_{2013}/B_{MSY} = 0.65$ $\Pr(B_{2013} < 0.7B_{MSY}) = 0.60$

Base Case Projection of Harvest Rates in 2012-2013



Base Case Projection of Exploitable Biomass and Catch

